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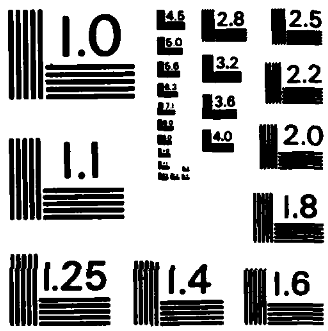

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

PARAMETRIC ANALYSIS
OF
ECHOSOUNDER PERFORMANCE

by

Robert Judson Fuller

September 1985

Thesis Advisor: D.L. Walters

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This thesis seeks to understand the range limitations of the echosounder and to explore methods to quantify atmospheric turbulence parameters at a given range. The

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Parametric Analysis of Echosounder Performance

by

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B.S., Fresno State University, 1975

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN PHYSICS

from the

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ABSTRACT

An echosounder is used to probe various atmospheric parameters. An acoustic wave is transmitted into the atmosphere and information deduced from the backscattered energy.

This thesis seeks to understand the range limitations of the echosounder and to explore methods to quantify atmospheric turbulence parameters at a given range. The propagation of the acoustic energy, including the effects of excess attenuation, are modeled to predict the performance of an echosounder when various parameters are changed. The electronics of an existing echosounder are investigated to understand inherent or design limitations.

Keywords: acoustic radar; acoustic sounders; computer programs.

TABLE OF CONTENTS

I. INTRODUCTION

Many atmospheric turbulence-dependent processes take place in the troposphere, the lowest ten to twenty kilometers above the earth's surface. Acoustic energy interacts with irregularities in the atmosphere more strongly than electromagnetic waves and is potentially a better probe for these irregularities. Acoustic echoes have been used to detect:

1) wind speed and direction profiles,
2) humidity profiles,
3) strength and location of temperature inversions,
4) temperature inhomogeneities,
5) mechanical turbulence.

The acoustic sounder, also known by the names echosounder, echosonde, sodar, and acoustic radar, transmits a pulse of acoustic energy into the atmosphere. The various atmospheric parameters can be determined based on the intensity and frequency of the scattered energy. The range to the scattering center is determined from the elapsed time between transmission and return of the scattered energy.

In this thesis we are attempting to improve our understanding of the fundamental range limitations of the acoustic sounder. In general, the acoustic sounder suffers

from multiple scattering. Turbulence at shorter ranges alters the phase front of the propagating pulse and reduces the magnitude of the return from longer ranges.

We are also exploring the use of return from shorter ranges, along with theory for the degradation of the energy along the path, to compensate for short range degradation in a boot-strap fashion and quantify the return from longer ranges. Acoustic sounders at present indicate the presence of inhomogeneities at a specific altitude but the magnitude of the inhomogeneities may have errors of a factor of four or more.

The following factors affect the range of the echosounder:

1) Atmospheric:

a) Pressure,

b) Temperature,

c) Temperature Structure Parameter C_T^2,

d) Velocity Structure Parameter Cv^2 ,

e) Water-vapor Pressure, and

f) Ambient Noise.

2) Echosounder:

a) Antenna Aperture Factor,

b) Antenna Diameter,

c) Efficiency,

d) Frequency,

e) Power Transmitted, and

f) Pulse Length.

II. BACKGROUND

Acoustic energy propagates in the atmosphere as a longitudinal wave of pressure variations. The energy is scattered, attenuated, and refracted. Energy which is scattered constitutes the returned signal. The attenuation decreases the energy ensonifying a given volume and decreases the returned signal. Energy that is scattered through small angles or that is refracted results in further degradation or excess attenuation of the signal.

A. SCATTERING

The echosounder transmits a pulse of acoustic energy that is scattered by temperature and velocity inhomogeneities. Information about the inhomogeneities is then based on elapsed time between transmission and receipt of the return signal, the strength of the returned signal, the equations for scattering, and the Doppler shift. Variations in the propagation velocity of the wave, which are a function of the temperature and velocity variations in the air mass, produce the scattering. In addition to scattering, the temperature variations cause refraction while the velocity turbulence causes both a shift in phase and direction of propagation [Ref. 1:p. 60].

Random temperature or wind structure caused by turbulence and uniform gradients of temperature or velocity contribute to the scattering. The gradient must change in a scale size that is comparable to or smaller than the acoustic wavelength in order to contribute to the scattering. It appears that the effects of uniform gradients are limited to beam bending and possible specular reflection for the acoustic frequencies of interest here. This refractive structure of the troposphere and stratosphere would be better probed with what has come to be called infrasound, sound of frequencies below twenty Hertz. [Ref. 1:p. 52]

The turbulent atmospheric temperature and velocity fluctuations, at high wave number, follow the Kolmogorov $K^{-5/3}$ power spectral density law (in one dimension). The fluctuations are correlated spatially on the order of one centimeter to tens of meters. The nonzero correlation lengths and the declining power spectral density imply a different scattering process than for random point scatterers, even though the turbulence is a stochastic process [Ref. 1:p 61].

An expression for the power scattered from a unit volume per unit incident flux into a unit solid angle is [Ref. 2:p 84]

$$\sigma = \frac{.055}{\lambda^{1/3}} \cos^2\theta \left(\frac{Cv^2}{c^2} \cos^2\left(\frac{\theta}{2}\right) + .13\, \frac{Ct^2}{T^2}\right)\left(\sin\left(\frac{\theta}{2}\right)\right)^{-11/3},$$

where

is the wavelength of the transmitted sound,

T is the average atmospheric temperature,

O is the angle of scattering from the direction of propagation,

Cv^2 is the velocity structure parameter,

$$Cv^2 = \frac{\langle V(x) - V(x+r)\rangle^2}{r^{1/3}} ,$$

and Ct^2 is the temperature structure parameter,

$$Ct^2 = \frac{\langle T(x) - T(x+r)\rangle^2}{r^{1/3}} .$$

This scattering equation indicates that backscatter ($\theta = \pi$) is only a function of the temperature structure. The velocity at any point is the vector sum of the phase velocity of the sound and the particle velocity of the turbulence. This vector sum is always in the forward direction because the particle velocity is always less than the speed of sound c. Therefore the backscatter is only a function of the temperature structure [Ref. 1:p 60]. The vertical turbulent velocity does cause a Doppler shift of the frequency of the backscattered radiation.

Scattering over a region with correlated scattering centers produces constructive and destructive interference. The backscattered waves are partially coherent. This results in much greater intensities than would be received from incoherent scattering such as Rayleigh scattering [Ref.

1:p 61]. Also the scattering with the interference, over the nonzero coherence length, acts like an array of scattering centers in a regular crystal lattice of spacing L. The Bragg condition

$$L = \frac{\lambda}{2} / \sin(\theta/2),$$

is satisfied. The dominant scattering is for scale sizes of $\lambda/2$. [Ref. 1:p 61]

B. ATTENUATION

The atmosphere absorbs some acoustic energy that propagates through the atmosphere and reradiates this energy at different frequencies. Quantitatively the power lost (P_l) over a path length l is given by

$$P_l = e^{-\alpha l},$$

where is the attenuation coefficient in Nepers per meter. Historically the attenuation coefficient has been considered to be the sum of several terms;

α_{cl} = classical viscous losses,

α_r = molecular rotation losses,

α_{vib} = molecular vibrational losses, N_2 and O_2.

Classical and rotational loses are negligible below about three kilohertz, the region of interest for echosounder operation [Ref. 1:p 54 and Ref. 3:p. 18-2], consequently vibration of N_2 and O_2 produce most of the attenuation.

Rotational and vibrational losses are referred to as relaxation processes. The acoustic energy excites internal energy modes of the N_2 and O_2 molecules. The rate of collisions with water vapor determines the rate and efficiency of conversion of the energy into translational energy (heat).

The phase is shifted due to the relaxation processes. This is one of the reasons some of the microwave radar pulse compression techniques cannot be used in echosounders. A number of the pulse compression techniques rely on the phase not changing during propagation.

The dependence of the attenuation on the water vapor pressure is believed to be due to a resonance process between the lowest vibrational states of the O_2 and N_2 molecules with the water molecules. Henderson and Hertfeld in Reference 4 [p.986] state that the lowest vibrational states of O_2 and water vapor are only thirty-nine wavenumbers (56^0K) apart at 1600 cm^{-1}. For this reason oxygen was thought to be primarily responsible for the humidity dependent absorption of sound. Henderson and Herzfeld [Ref. 4], and many others, assumed nitrogen was an inactive dilutent having no effect on the relaxation processes [Ref. 4:p. 987]. Unfortunately the theory did not agree with the data for low frequencies and high humidities.

Theory incorporating the relaxation processes involving nitrogen and water at low frequencies and relative humidities greater than twenty-five percent bring the theory into agreement with the data. At high frequencies and low relative humidities, theory and data match well with oxygen making the main contribution and nitrogen acting as an inert dilutent. At low frequencies and high humidities, nitrogen seems to make the main contribution and oxygen acts as an inert dilutent. For the range of relative humidities in which many people live and over a good part of the audible frequency range it appears nitrogen is the major contributer to the relaxation processes [Ref. 5:p. 165]. This is in contrast to the previous assumption that oxygen was responsible [Ref. 6:p. 604].

An expression for attenuation due to the molecular absorption is given by [Ref. 7:p. 34],

$$\alpha = \frac{\alpha_{max}}{304.8}\left[\left(\frac{.018*f}{fm}\right)^2 + \left(\frac{2*(f/fm)^2}{1+(f/fm)^2}\right)^2\right]^{1/2},$$

in dB/m,

where

f is the frequency of the transmitted pulse,

f_m is the Napier frequency,

$$f_m = (10+6600\ h+4400\ h^2)\left(\frac{P}{1014}\right)\left(\frac{519}{1.8T+492}\right)^{0.8},$$

$$\alpha_{max} = .0078\ f_m\left(1.8\ T+492\right)^{-2.5} \exp\left(7.77\left(1-\frac{519}{1.8T+492}\right)\right),$$

where

T is temperature in degrees Celcius,

h is the percent mole ratio of water vapor,

h= 100 (e/p),

e= water vapor pressure in mb,

P= atmospheric pressure in mb,

To convert from dB/m to Nepers/m note that

$10 \log(I(x)/I(0)) = 10 \log(\exp(-\alpha x)$,

$\Longrightarrow 4.34\,\alpha(\text{Nepers/m}) = \alpha\,(\text{dB/m})$.

The Napier frequency is the frequency of maximum absorption per wavelength and α_{max} is the attenuation at the Napier frequency. The Napier frequency is shifted to higher frequencies by even small amounts of water vapor. Plots of attenuation versus water-vapor pressure in millibars (Figure 1) and versus relative humidity (Figure 2) are shown for a range of frequencies.

For a given temperature, the attenuation has a maximum and decreases for higher or lower humidities. With higher temperatures, the maximum attenuation increases and the relative humidity at which that maximum occurs decreases. Plots of attenuation versus water-vapor pressure in millibars (Figure 3) and versus relative humidity (Figure 4) are shown for a range of temperatures.

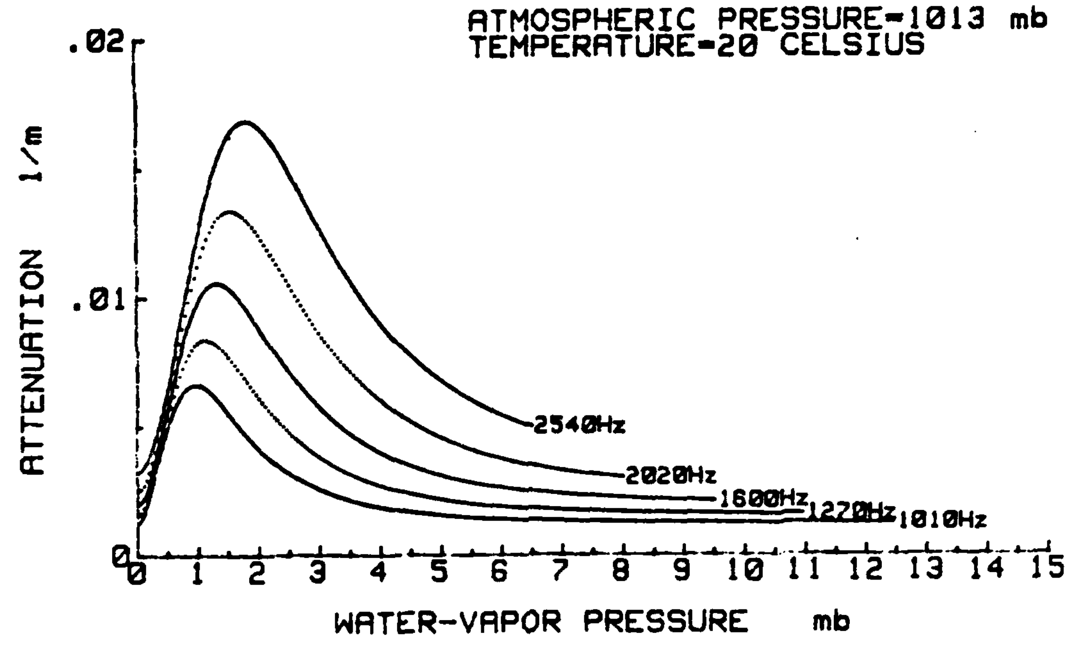

Fig. 1. Attenuation versus Water-vapor Pressure (mb.) for Frequencies around 1.6 KHz.

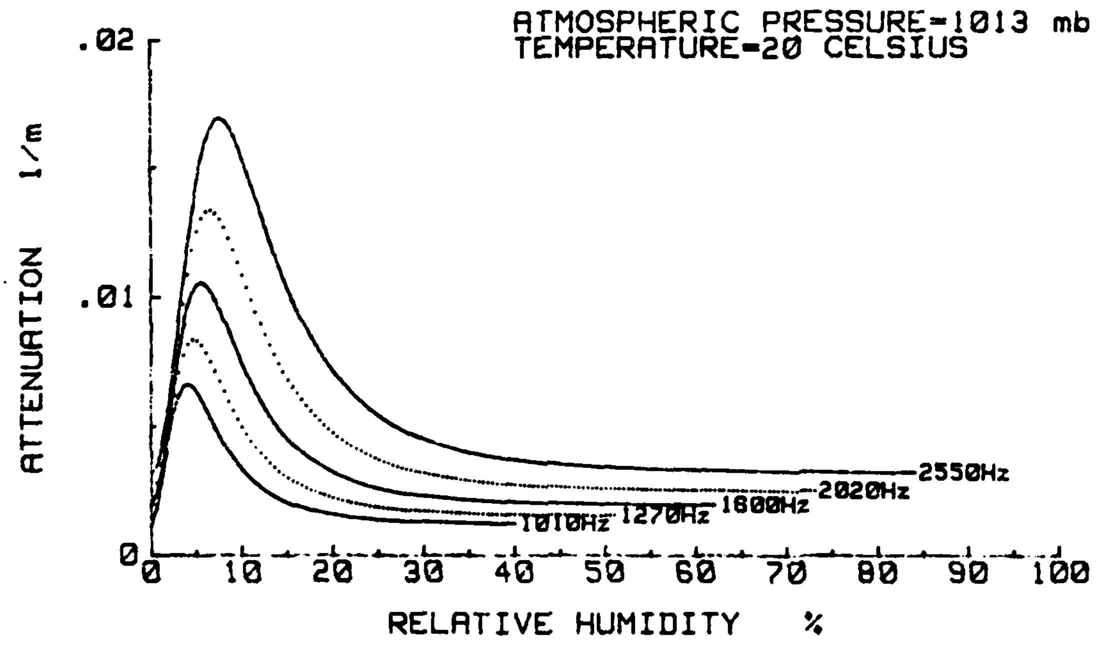

Fig. 2. Attenuation versus Relative Humidity (%) for Frequencies around 1.6 KHz.

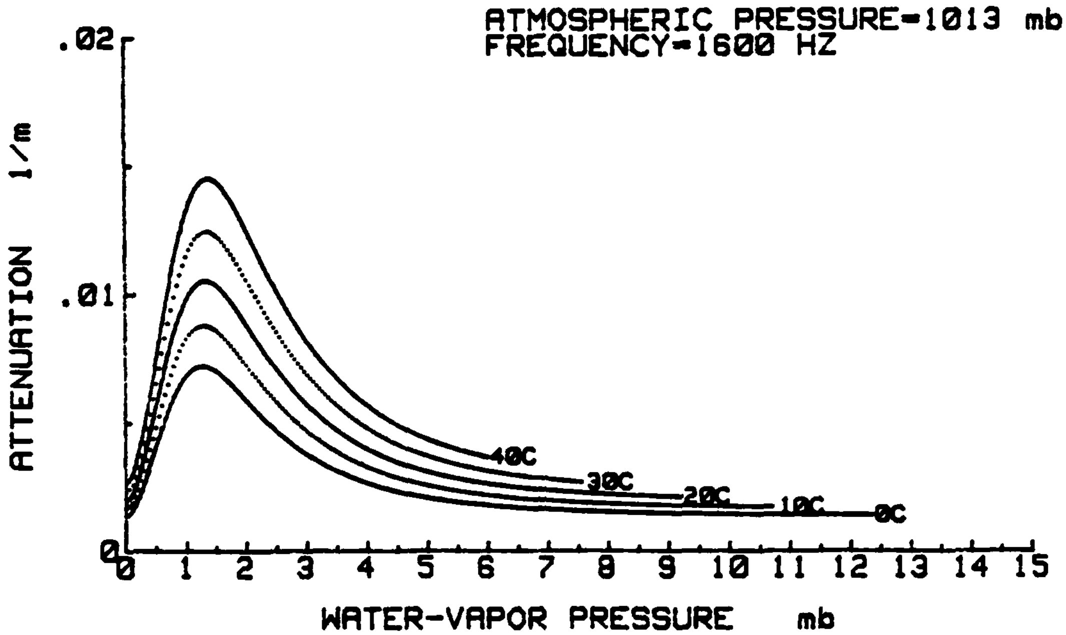

Fig. 3. Attenuation versus Water-vapor Pressure (mb.) for Temperatures Around 20 Celsius.

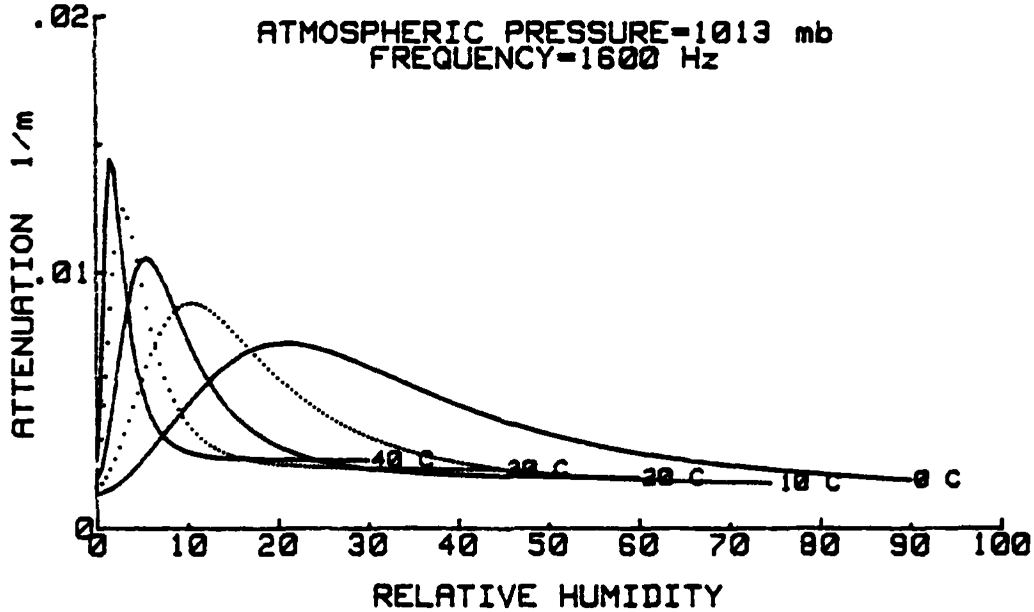

Fig. 4. Attenuation versus Relative Humidity (%) for Temperatures around 20 Celsius.

C. EXCESS ATTENUATION

The atmosphere scatters and attenuates the acoustic energy. In the previous section on scattering, we were only concerned with the energy scattered from a given volume. Excess attenuation accounts for scattering and energy loss for the round trip in the atmosphere to and from a given volume of interest. Excess attenuation arises because the atmosphere degrades the mutual coherence of the acoustic wave. The divergent solid angle of the acoustic wave is larger than would occur for a coherent, diffraction limited wave.

The excess attenuation, Ze^2, accounts for this energy lost due to small-angle scattering. This turbulent beam broadening reduces the on axis intensity. Clifford and Brown in Reference 8 [p. 1972] develop the equation

$Ze = 1/(1+N)$ for $N<1$,

$Ze = 1.5/(1+N)$ for $N>1$,

where

$N = (D_0/\rho_{0e})^2$,

D_0= antenna diameter,

ρ_{0e} is the atmospheric acoustic coherence length

$$= 1.46*k^2 *\int_0^{R0} ds*Cn_e{}^2(s)*\left(\left(\frac{1-s}{2R_0}\right)^{5/3}+\left(\frac{s}{2R_0}\right)^{5/3}\right)^{-3/5} .$$

The term varies from a value of one for no excess

attenuation to an asymptote of zero, implying the energy would be spread over a 2π solid angle.

There is a step in the functional dependence of the excess attenuation when N=1 that can be seen in the equations above and in the plots. There clearly is no physical discontinuity but rather a transition between the theoretical dependence between two asymptotic regions.

Figures 5,6, and 7 are plots of excess attenuation versus range for antenna sizes of .5, 1, and 1.5 meters, respectively, for several frequencies. As can be seen from these plots or the equations above, the relationship of the antenna size to the coherence length has a significant effect on the excess attenuation. A larger antenna will not, by itself, produce greater range. The antenna size must be matched to the transmission frequency in terms of antenna design guidelines and effects upon the excess attenuation.

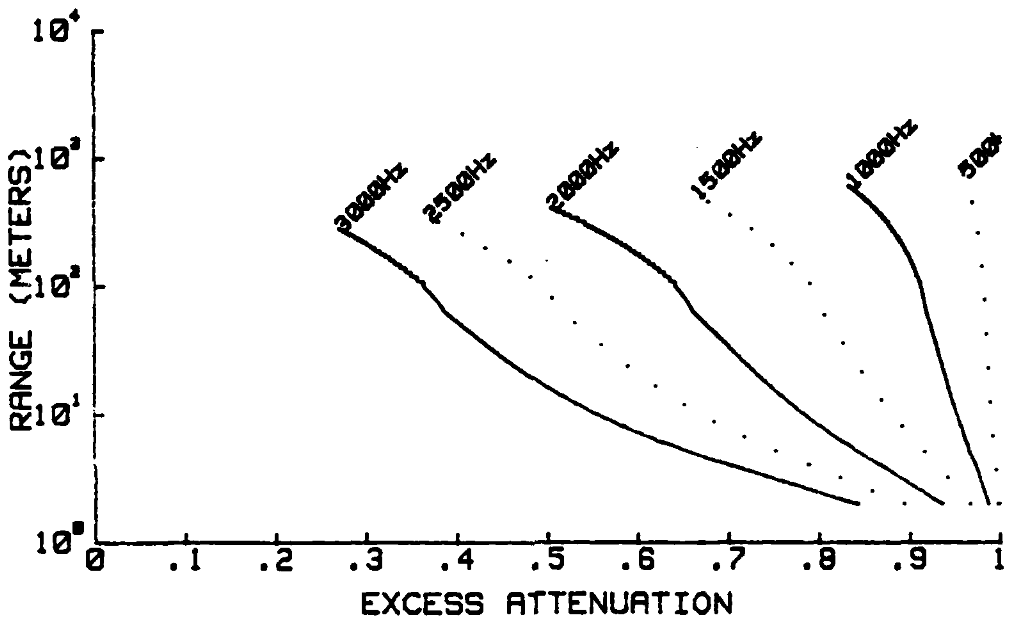

Fig. 5. Range versus Excess Attenuation for an Antenna Diameter of .5 m.

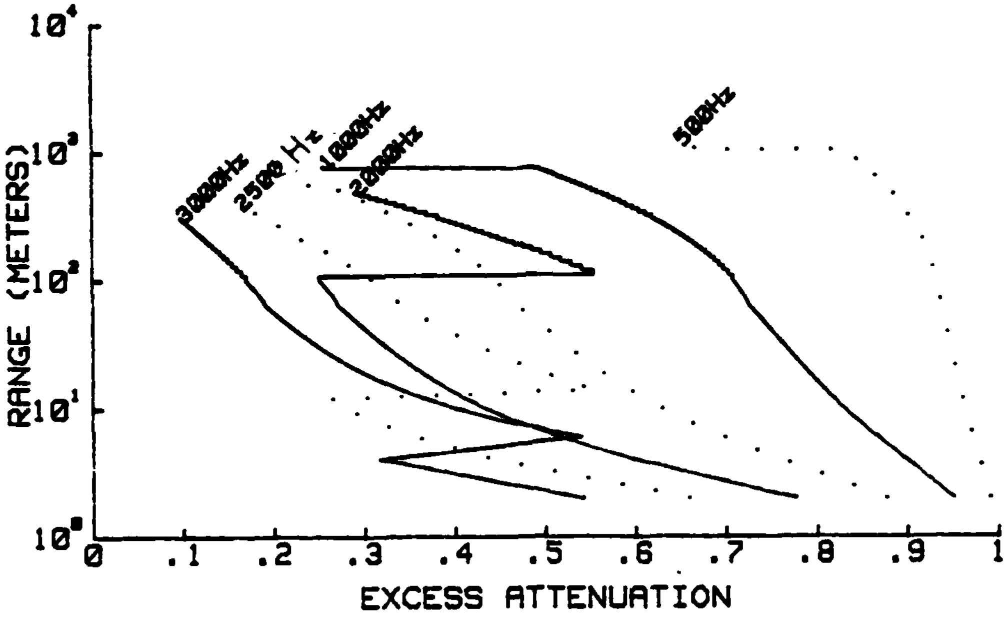

Fig. 6. Range versus Excess Attenuation for an Antenna Diameter of 1.0 m.

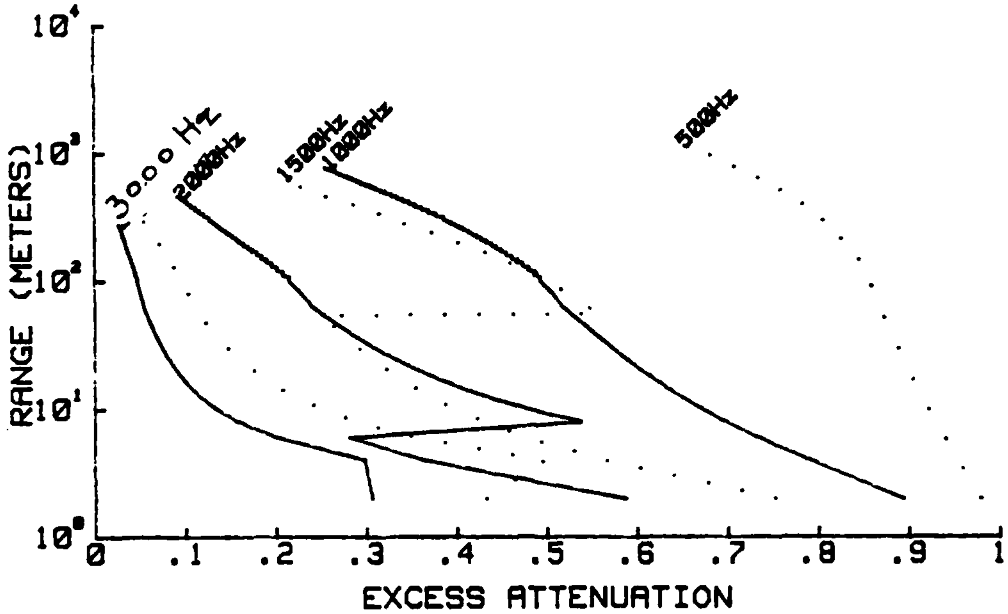

Fig. 7. Range versus Excess Attenuation for an Antenna Diameter of 1.5 m.

III EXPERIMENT

The acoustic sounder is an excellent tool for probing the lower troposphere. It suffers from several shortcomings:

1) The range has typically been limited to a few hundred meters.
2) It has proven difficult to quantify the measurements accurately for a given range.

In this thesis, we approached the problem from several directions. We looked at the hardware to understand the signal to noise limitations and to understand how the magnitude of the returned signal could be calibrated. We developed a software model which would allow one to estimate the power backscattered from the atmosphere at a given range, based on profiles of atmospheric characteristics and input parameters for the acoustic radar.

A. HARDWARE

The acoustic sounder we were working with was the Aerovironment Model 300. It consists of an electronic module which generates a 1600 Hertz electrical pulse. The pulse is converted to acoustic energy by a transducer which feeds a 1.25 meter parabolic reflector. Energy

backscattered by the atmosphere is then received by the reflector and transducer. The electrical signal is then filtered and amplified. In addition, a ramp amplifier compensates for the 1/r decreasing signal amplitude with range to decrease the dynamic range requirements of the present data display, a strip chart recorder.

We replaced the various integrated circuit amplifiers and filters with more current designs with lower noise. We replaced the pre-amplifier with an OPA 111 and the rest with LF 356 BN devices.

We traced the amplifier and filters of the receiver board to understand the undocumented choices the manufacturer had made. Figures 8 and 9 show a pre-amplifier, high and low pass filters and two stage amplification. The filters are bi-quad configured with notched outputs. Figure 10 shows the notching. Figure 10 represents the frequency spectrum output of the receiver board as measured with the HP 3561A Frequency Spectrum Analyser with random noise from the HP 3561A providing the input signal before the filters. Figure 11 represents frequency spectrum of the receiver board with the random noise across the transducer. A 10^5 ohm resistor was used to match impedences as shown in Figure 12.

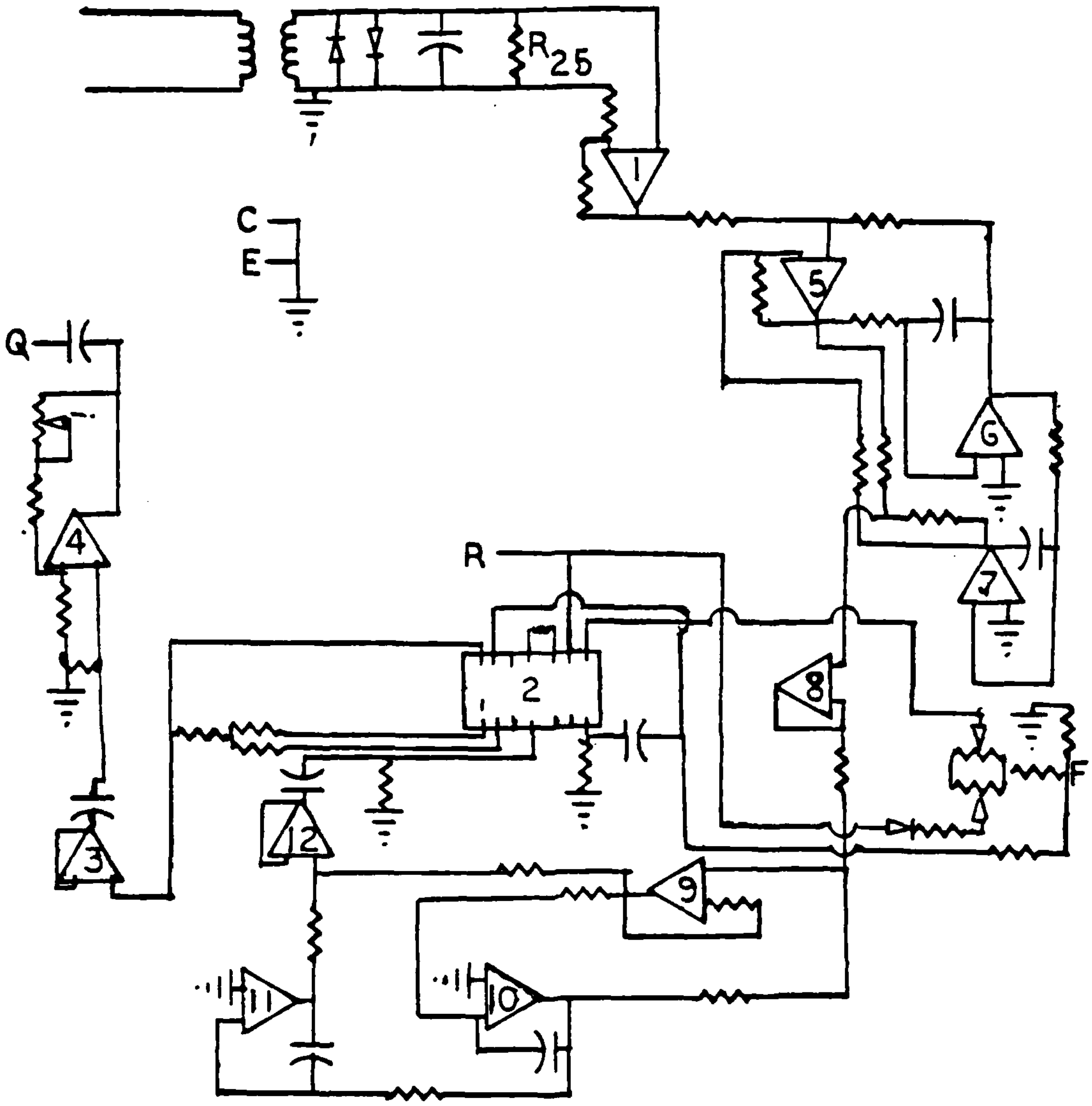

Fig. 8. Schematic of the Receiver Board of the Aerovironment Model 300.

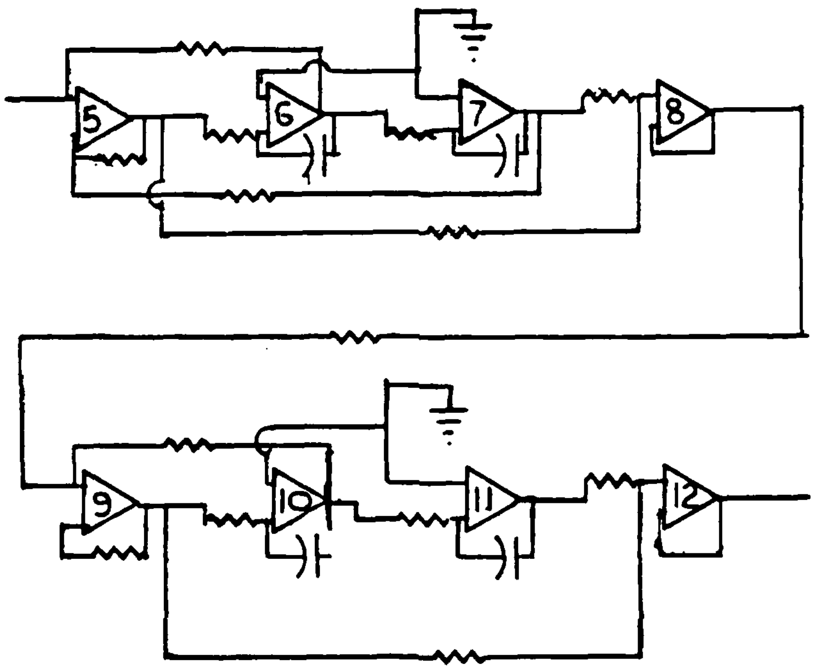

Fig. 9. Schematic of the High and Low Pass Filters of the Receiver Board of Aerovironment Model 300.

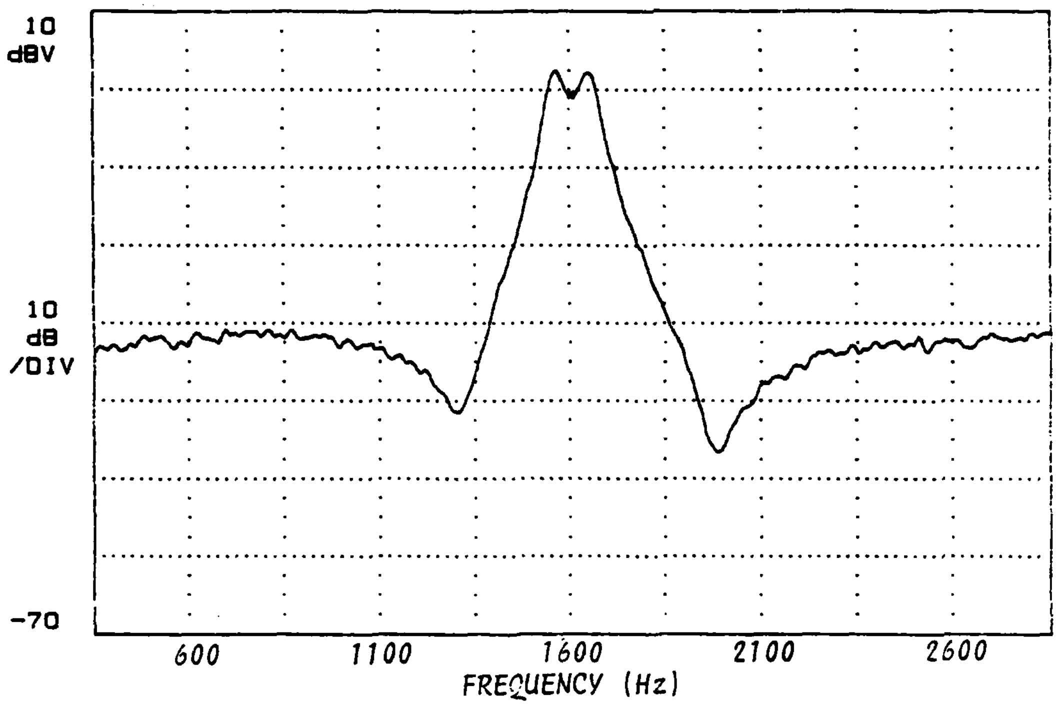

Fig. 10. Frequency Spectrum of the Receiver Board of the Aerovironment Model 300. (Input before filters)

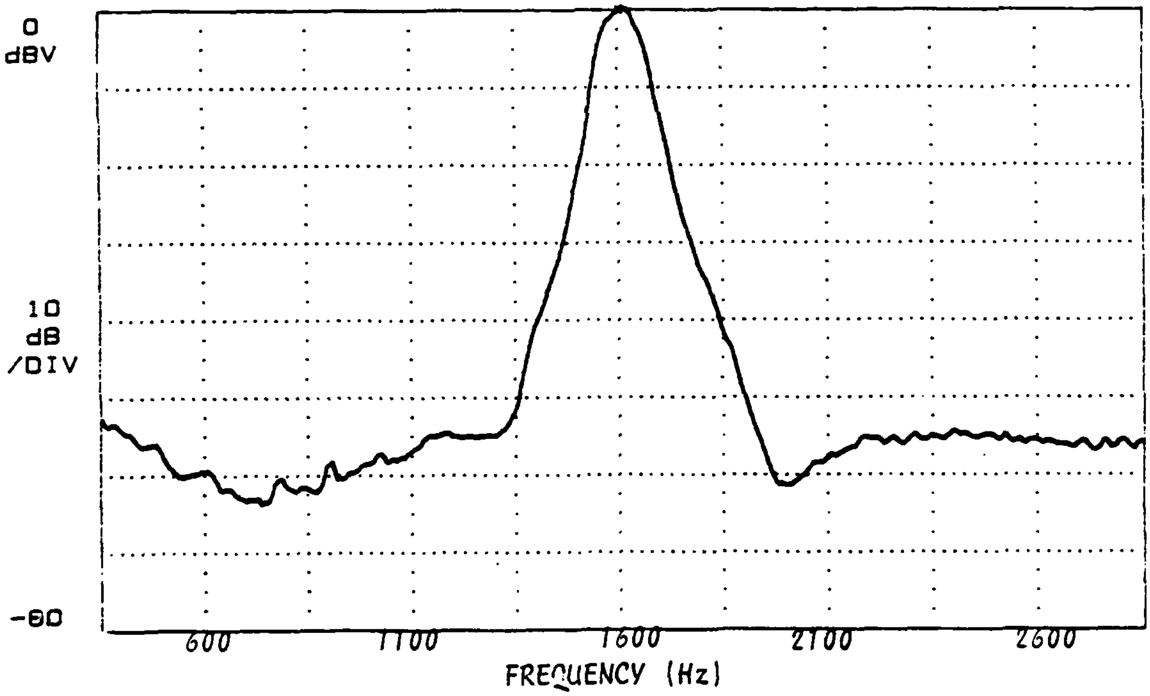

Fig. 11. Frequency Spectrum of the Receiver Board of the Aerovironment Model 300. (Input across transducer)

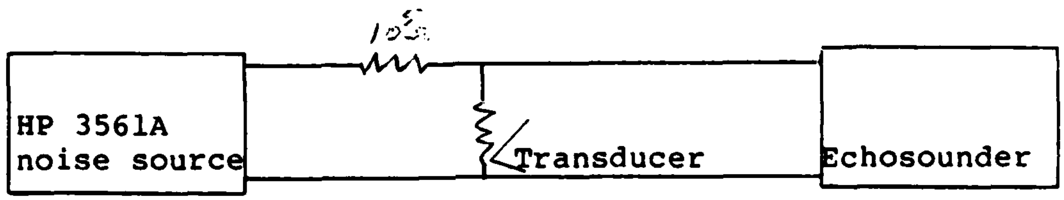

Fig. 12. Connection of Noise Source to Transducer

The manufacturer had a filter-oscillator board after the receiver board with a switch for three pass bands; narrow, medium, and wide. With the same input as in Figure 10 we measured the frequency output for the three settings of the filter-oscillator board (Figure 13). As can be seen, there is little difference between the three settings.

From previous measurements, the resistor labeled R_{25} in the schematic (Figure 8) of the receiver board was found to load down the input. The resistor was initially 25 kilo-ohms. Figures 14, 15, and 16 represent the signal from the input transformer with R_{25} =25K, 100K, and ∞ ohms respectively. Random noise from the HP 3561A was input across the transducer as shown in Figure 12. The Q of the input transformer was improved by increasing the resistance. The lower curve in each Figure is with no noise signal input from the HP 3561A.

It appeared the Q of the filters could also be increased by adding the resistors labeled R_0 in Figure 17. The upper curves in Figures 18, 19, and 20 are the output of the receiver board with each $R_0=\infty$, 750, and 560 ohms

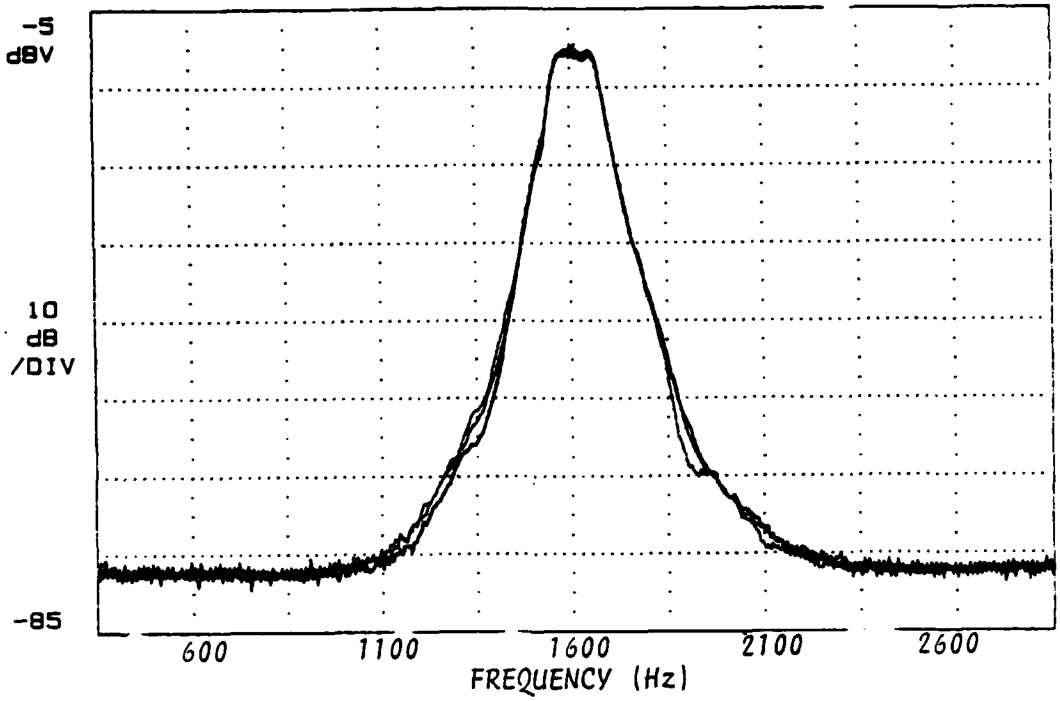

Fig. 13. Frequency Spectrum of the Filter Oscillator Board of the Aerovironment Model 300. (Input before the filters of the receiver board)

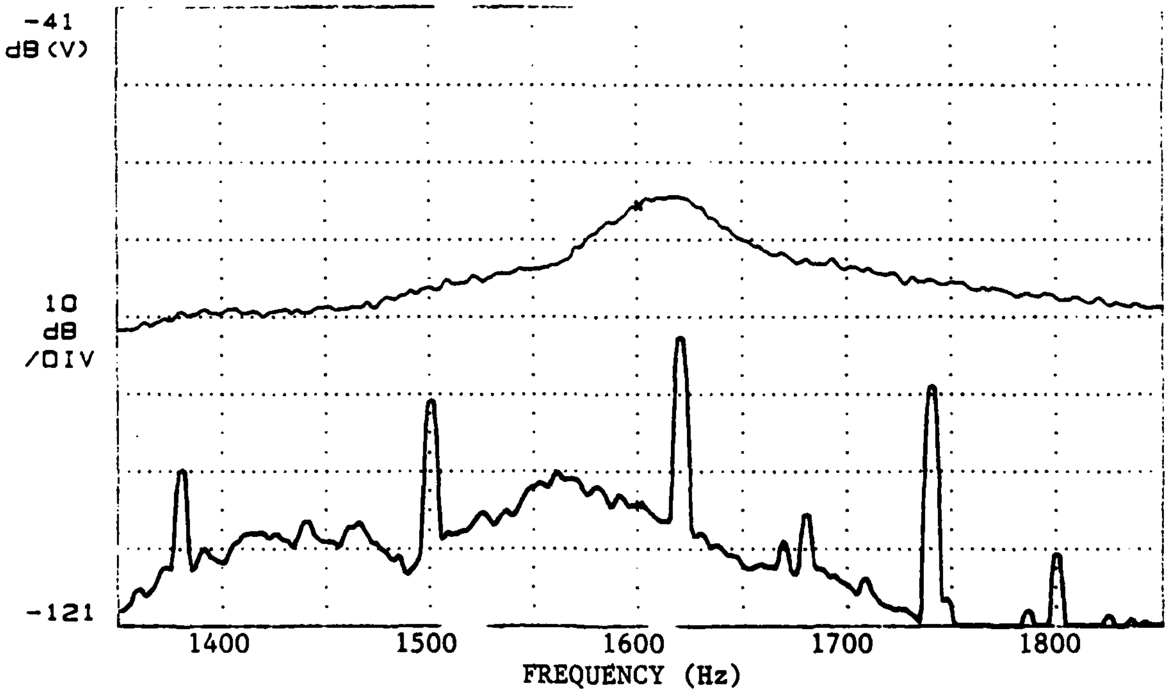

Fig. 14. Frequency Spectrum of the Input Transformer (Input across transducer with R_{25}=25_k).

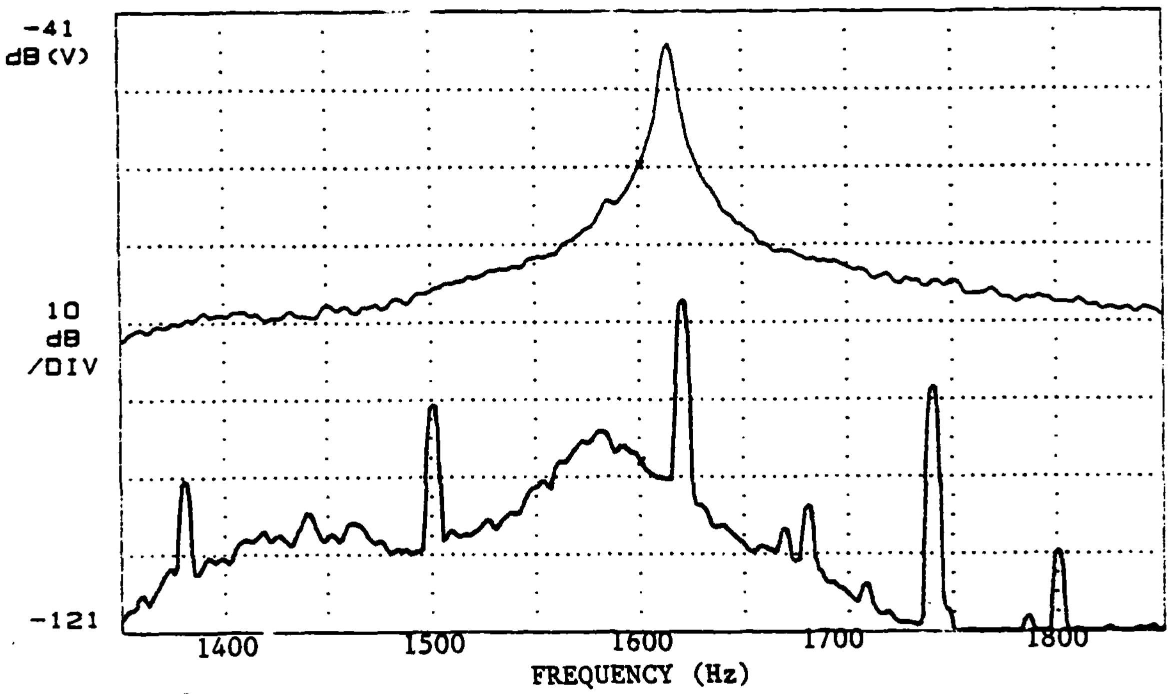

Fig. 15. Frequency Spectrum of the Input Transformer (input across transducer with R_{25}=100k)

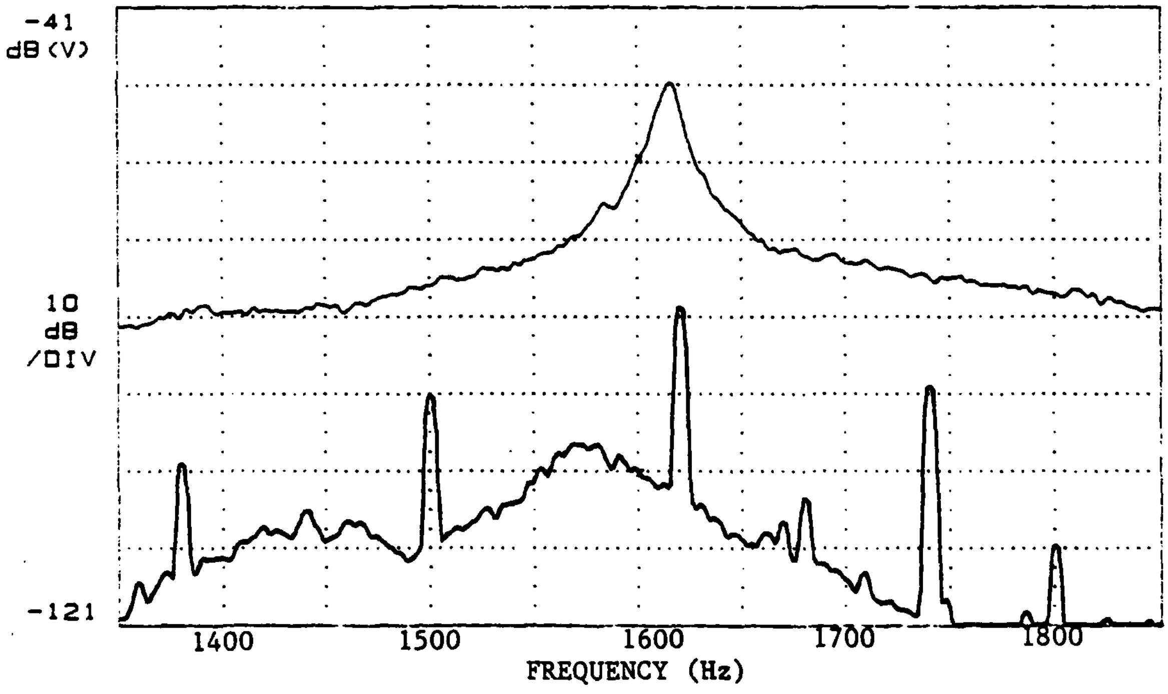

Fig. 16. Frequency Spectrum of the Input Transformer (input across transducer with $R_{25}= \infty$)

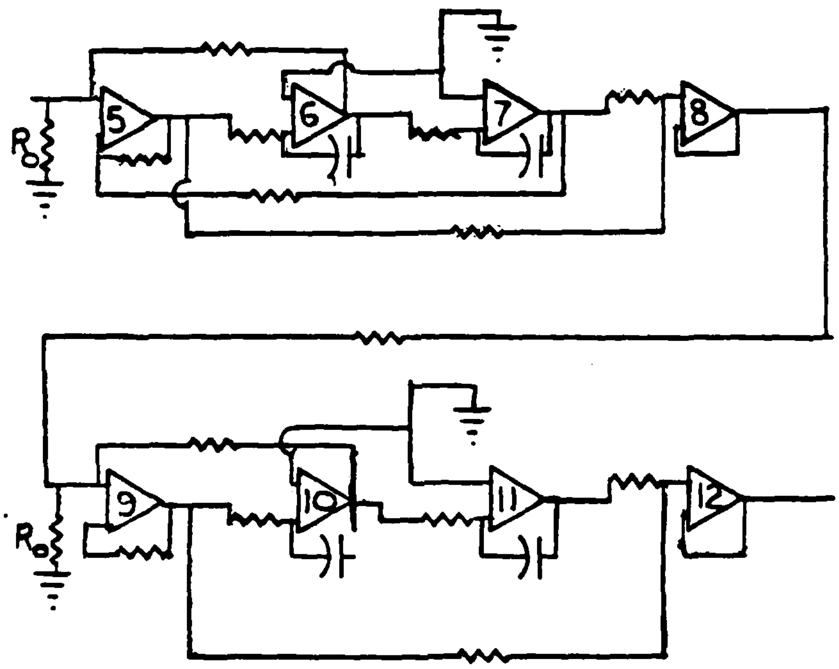

Fig. 17. Schematic of the Receiver Board with R_0

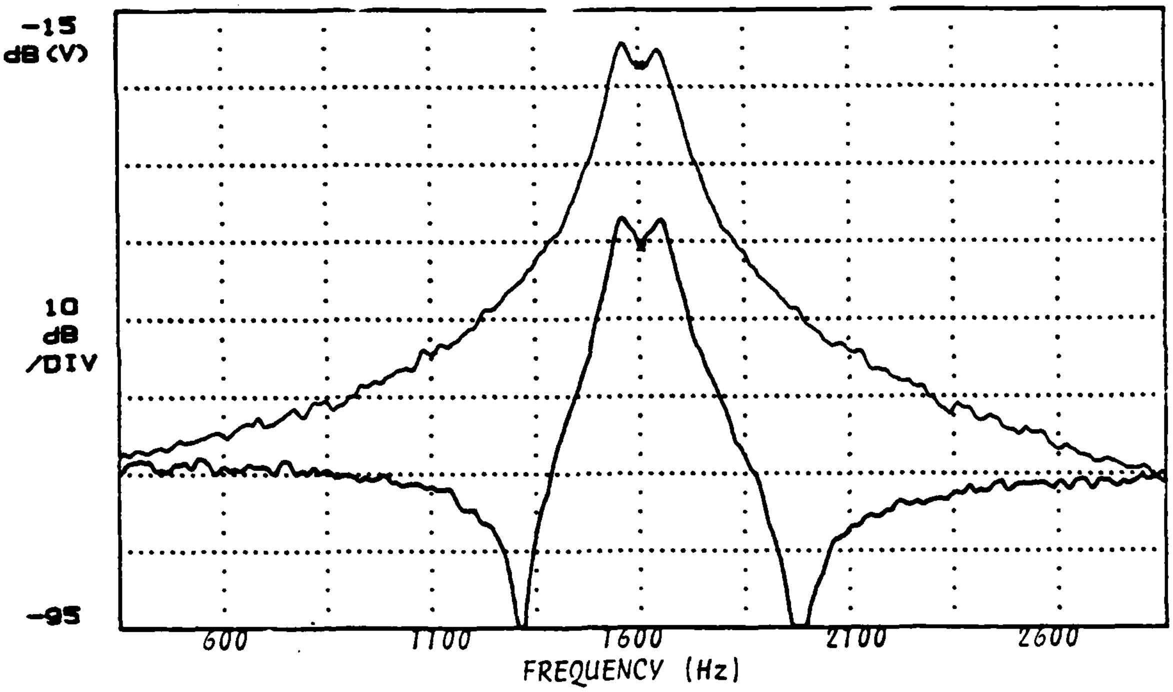

Fig. 18. Frequency Spectrum of the Receiver Board with $R_0 = \infty$ (input before filters)

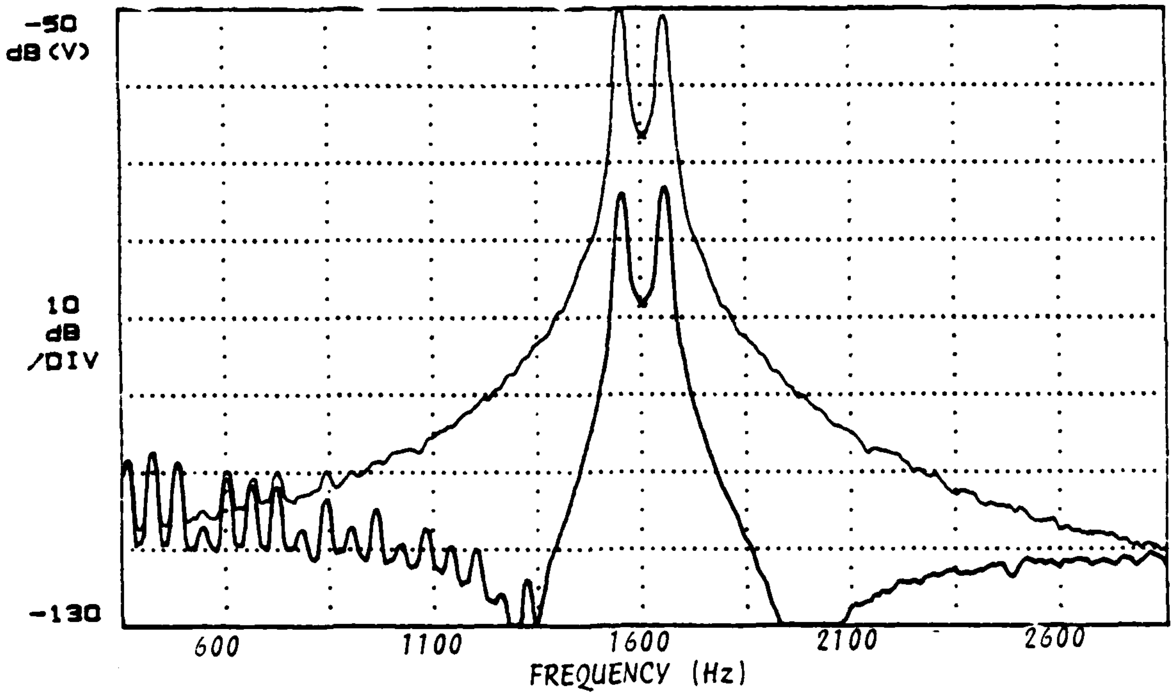

Fig. 19. Frequency Spectrum of the Receiver Board with $R_0 = 750\ \Omega$ (input before filters)

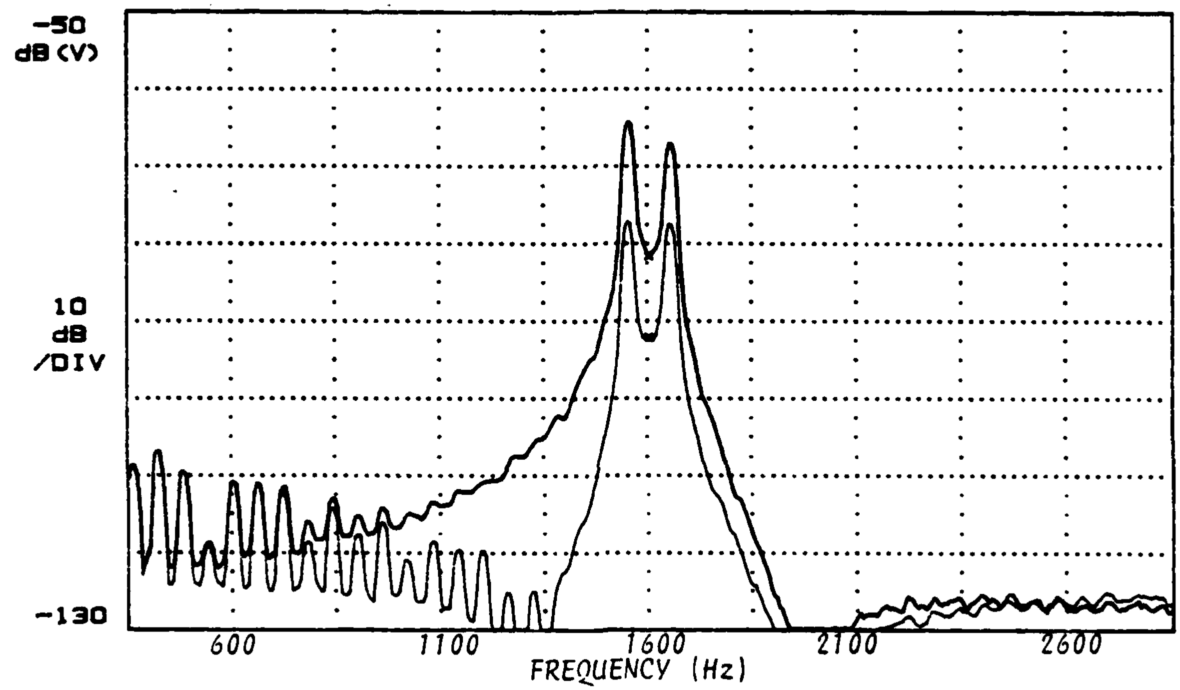

Fig. 20. Frequency Spectrum of the Receiver Board with R_0=560 Ω (input before filters)

respectively. The input was random noise from the HP 3561A after the pre-amplifier but before the filters of the receiver board. The effect of decreasing the resistance was an increase in gain but the pass-band was no longer flat on top. However, for the range of vertical wind velocities, about two or three meters per second, a pass-band of fifty or sixty Hertz is adequate to allow for the Doppler shift. As can be seen, the filters could be tuned for a narrow pass-band which would have better shape. We would gain amplification and still have a pass-band that is wide enough to meet our needs.

The lower curves in Figures 18, 19, and 20 are with notching, the upper without. The effect of the notching was a sharper cut off near the bandpass frequency (1600 Hz) but a loss at higher and lower frequencies.

B. SOFTWARE

The signal received by an acoustic sounder from a given range tells us that scattering centers exist but we can say little about the size and magnitude of the scattering centers. We don't know how much energy was incident on the scattering volume nor how much the signal was degraded on the return path. If, on the other hand, previous signals are used to determine the atmospheric characteristics then

an estimate of the degradation of the incident power and the degradation of the return signal can be made.

The software programs I have written here go in the opposite direction. Given certain atmospheric characteristics, the power returned is estimated. With the modules tested, it would then be a matter of turning it around to take actual data and estimate atmospheric conditions. In the present form they serve our purposes in allowing us to explore the effects of parameter changes.

All the programs are fundamentally built around the echosonde equation, also sometimes referred to as the radar equation in meteorology [Ref. 9 and Ref. 7:p. 3].

$$Pr = Er*(Pt*Et)*(\exp(-2\alpha R))*\sigma_0(R,f)*\left(\frac{c*\tau}{2}\right)*\left(\frac{A*G}{R^2}\right)*Ze^2,$$

where

Pr is the power returned from a range R,

Pt is the power transmitted at frequency f,

Er is the efficiency of conversion of acoustic power to electrical power by the transducer ,

Et is the efficiency of conversion of electrical power to acoustic by the transducer,

c is the speed of sound in m/sec,

τ is the pulse length,

A is the area of the antenna,

R is the range, and

G is the effective-aperture factor of the antenna.

Transducer efficiencies must be measured for each driver and typically range from a few percent [Ref. 7:p. 3] to twenty five percent [Ref. 10:p. II-10].

The scattering cross section per unit volume (σ_0) is the fraction of incident power backscattered per unit distance into a unit solid angle at a given frequency. From Reference 7 [p. 4] and Reference 2,

$$\sigma_0 = .0039 * k^{1/3} * \frac{Ct^2}{T_0^2},$$

where

k is the wavenumber = 2π/wavelength,

T_0 is the local mean temperature in Kelvin,

Ct^2 is the temperature structure parameter,

The power scattered from a scattering volume is

$Pb(I)=(Pt*Et-Pb(I-1))*exp(-2\alpha R)*(c\tau/2)*Ze^2*\sigma_0$,

The power returned to the antenna is

$Pr=Pb*A*G*Er/R^2$,

where the return path attenuation was already included in Ps. The excess attenuation Ze^2 was discussed in the background section.

The dependence with height of the velocity structure parameter Cv^2 was needed for the calculation of the excess attenuation. Reference 2 and Reference 11 [p.149] give

$Cv^2 = 2 * \epsilon^{2/3}$,

where ϵ is the dissipation rate of turbulent kinetic energy.

Reference 11 [p. 154] and Reference (p 194) give

$$\epsilon = \frac{(.33m/s)^3}{k * R} * (1 + .07 * R^{3/5})^{3/2},$$

for a stable surface layer. Figure 21 is a plot of range versus this Cv^2.

The programs have four temperature structure parameter ($C_T{}^2$) profiles. The operator must choose one. The first is based on data as presented in Reference 13 [p. 398] for midday clear weather above the Tularosa Basin desert in New Mexico. The second choice is for the same data multiplied by a factor two to approximate looking up a convective plume. The third case for a nocturnal atmosphere assumes a dependence proportional to the negative exponential of the range as presented in Reference 13 [p. 399] with tower data from the same reference used for the first sixty-five meters. The fourth case assumes a dependence proportional to height to the -4/3 and a surface vertical heat flux of .095 [Ref. 7:p. 7]. Also case four allows for the operator to input the height of an inversion layer with $C_T{}^2$ being proportional to height to the -4/3 above the inversion layer. Figures 22, 23, 24, and 25 are plots of these four profiles.

Cv^2 and Ct^2 were then used to calculate the acoustic refractive index factor [Ref. 14:p. 119]

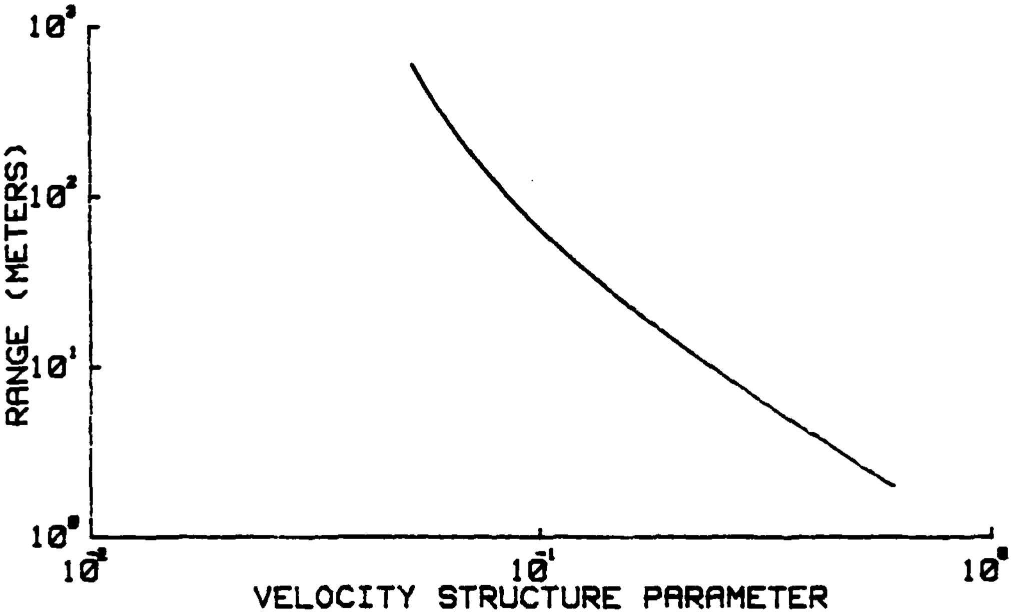

Fig. 21. Velocity Structure Parameter (C_V^2) Profile.

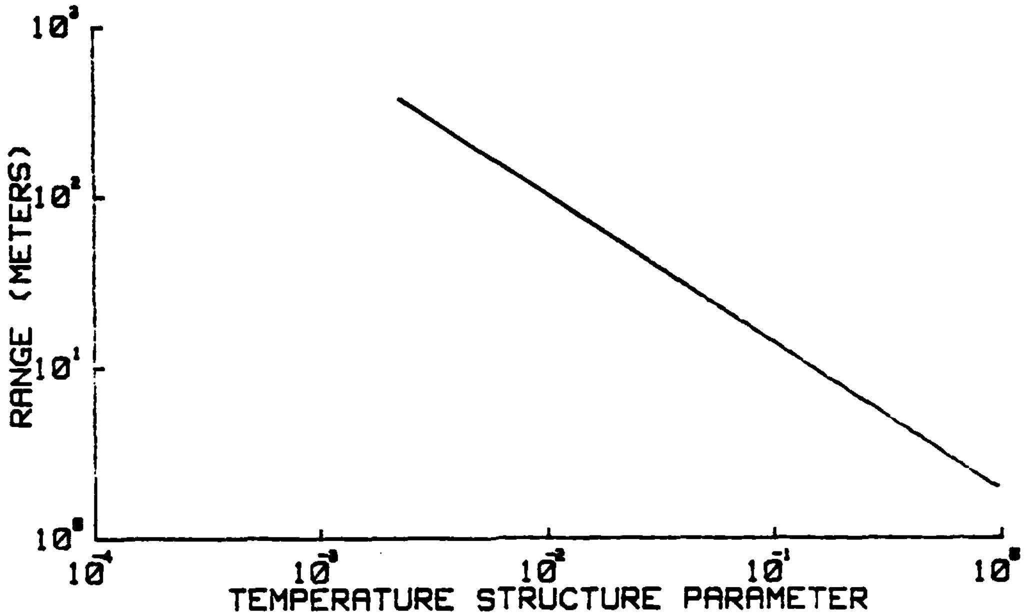

Fig. 22. Range versus Temperature Structure Parameter (C_T^2) for Profile 1

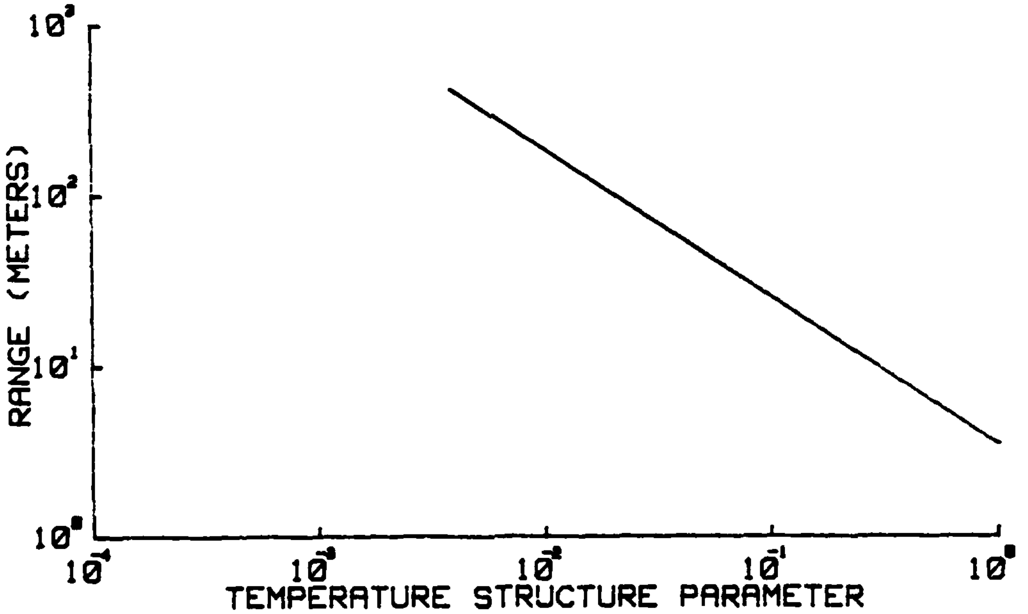

Fig. 23. Range versus Temperature Structure Parameter (C_T^2) for Profile 2

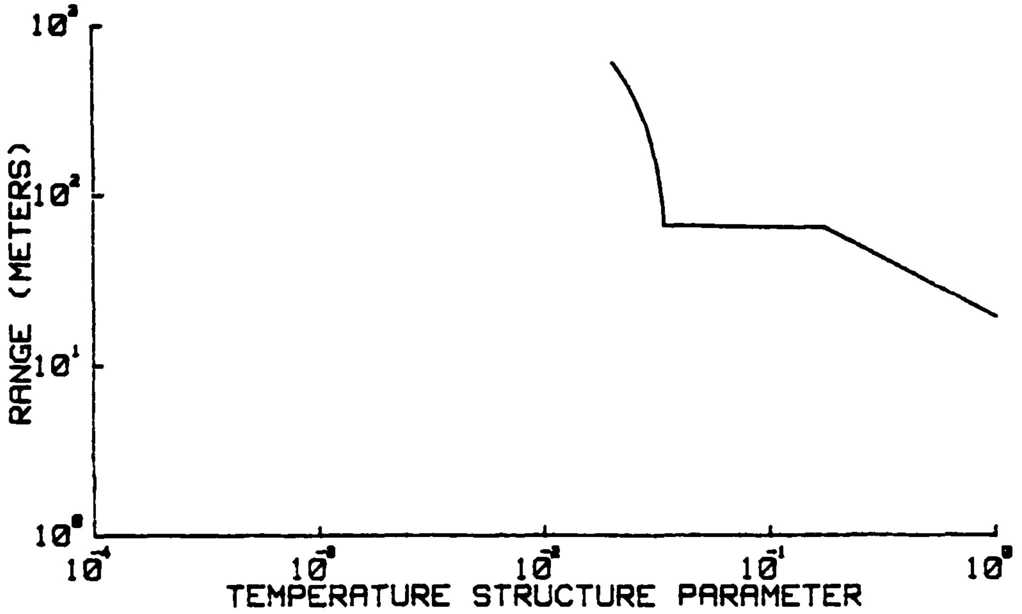

Fig. 24. Range versus Temperature Structure Parameter (C_T^2) for Profile 3

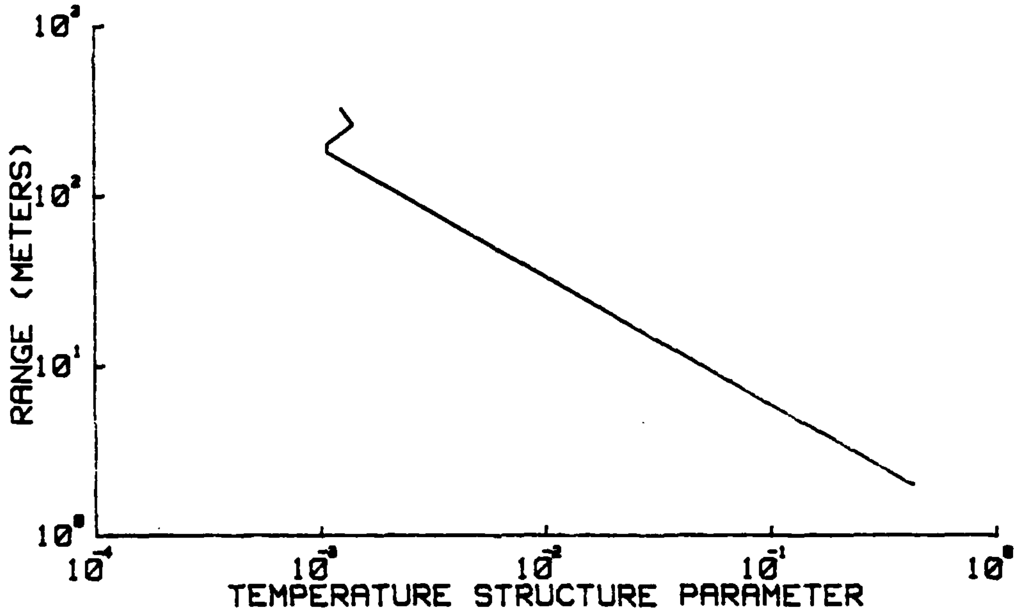

Fig. 25. Range versus Temperature Structure Parameter (C_T^2) for Profile 4

$$Cne^2 = \frac{Ct^2}{4T_0^2} + \frac{Cv^2}{c_0^2}$$

Figure 26 is a plot of Cne^2 using the third profile for Ct^2.

Figure 27 represents an input flow chart. It summarizes the effect of each variable or atmospheric parameter. Figures 28 and 29 are plots of the range versus the power returned to the echosounder for profiles 3 and 4.

The segments of the programs were tested against existing data to verify proper operation. Based on input temperature, atmospheric pressure, water-vapor pressure, and the frequency of operation of the acoustic sounder the programs calculate the attenuation. If the operator desires, the first program will plot the attenuation as a function of absolute water-vapor pressure and/or relative humidity for frequencies at one-third octaves around the input frequency and then again for temperatures at ten degree Celcius intervals around the input temperature. These plots were used to check the attenuation against data [Ref. 15] and [Ref. 5].

Ambient noise levels of acoustic sounders are found to be about ten to forty dB above the theoretical Johnson noise limit [Ref. 16:p. 19-4]. This noise level determines the maximum range. This maximum range is comparable to range capabilities of the Aerovironment System 300 when the operating parameters of the Aerovironment are used in the program.

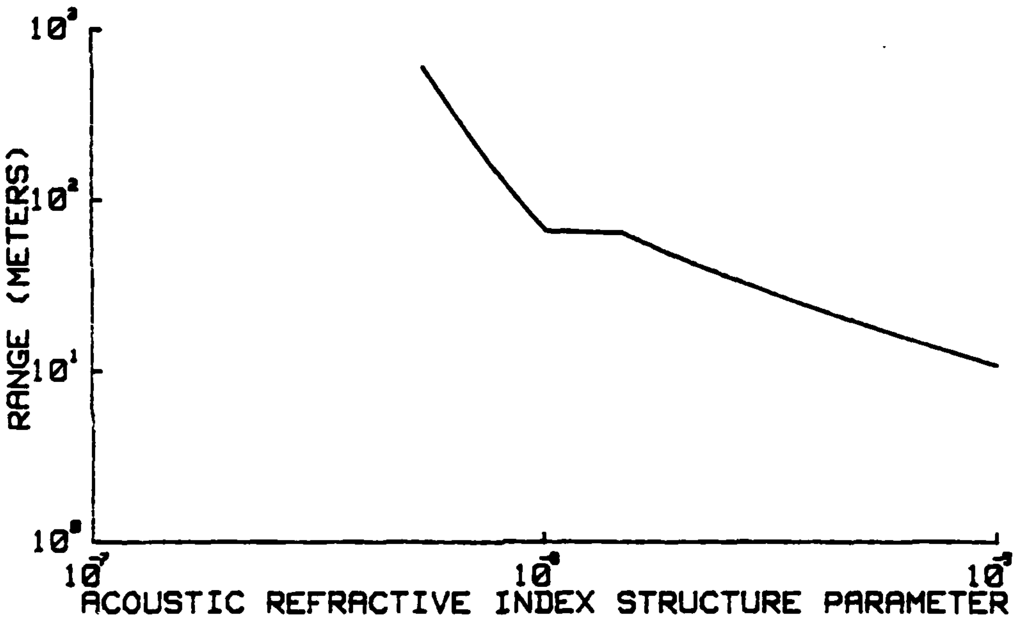

Fig. 26. Acoustic Index Structure Parameter ($C_{ne}{}^2$) Profile using $C_T{}^2$ Profile 3

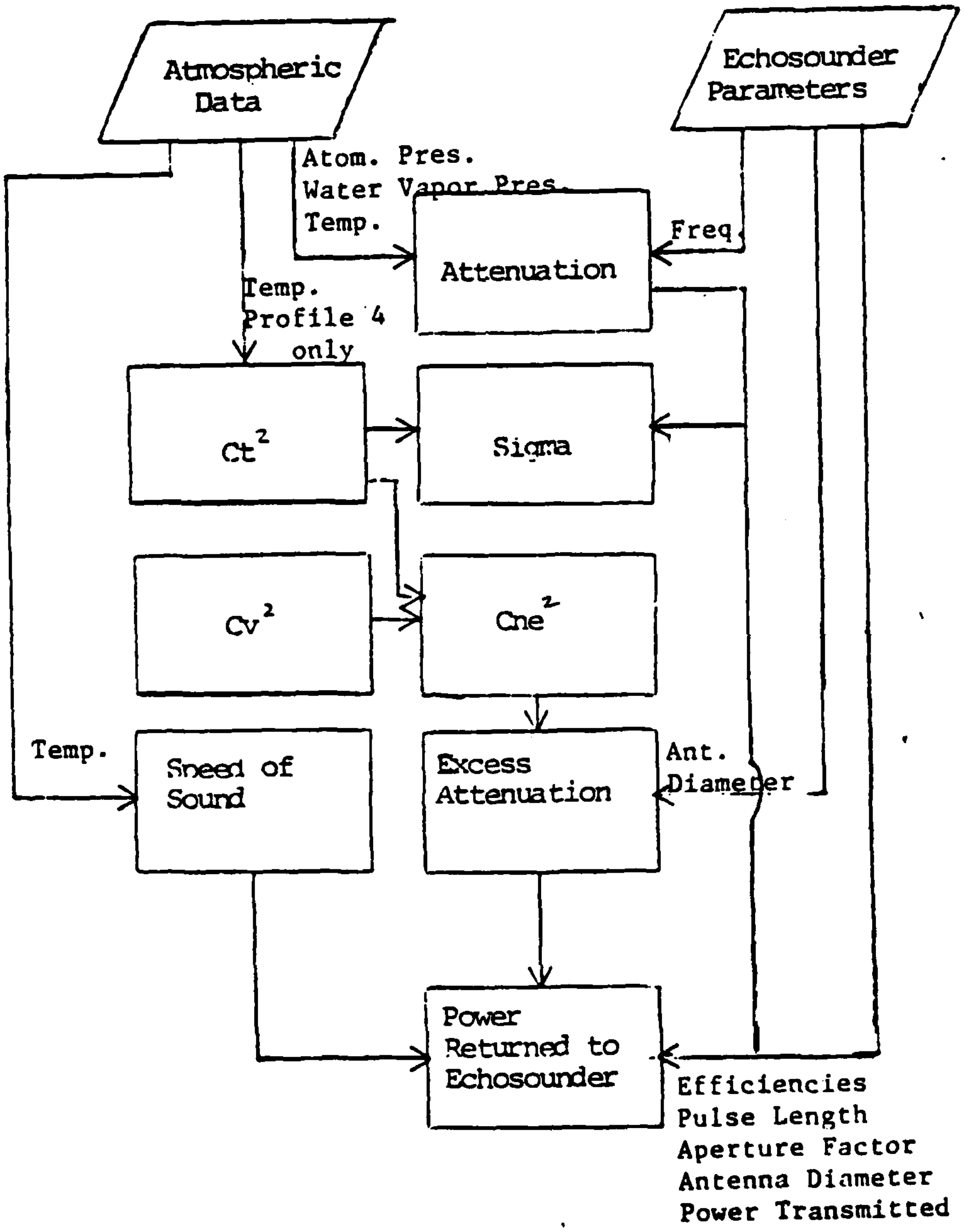

Fig. 27. Input Flow Chart for Computer Model

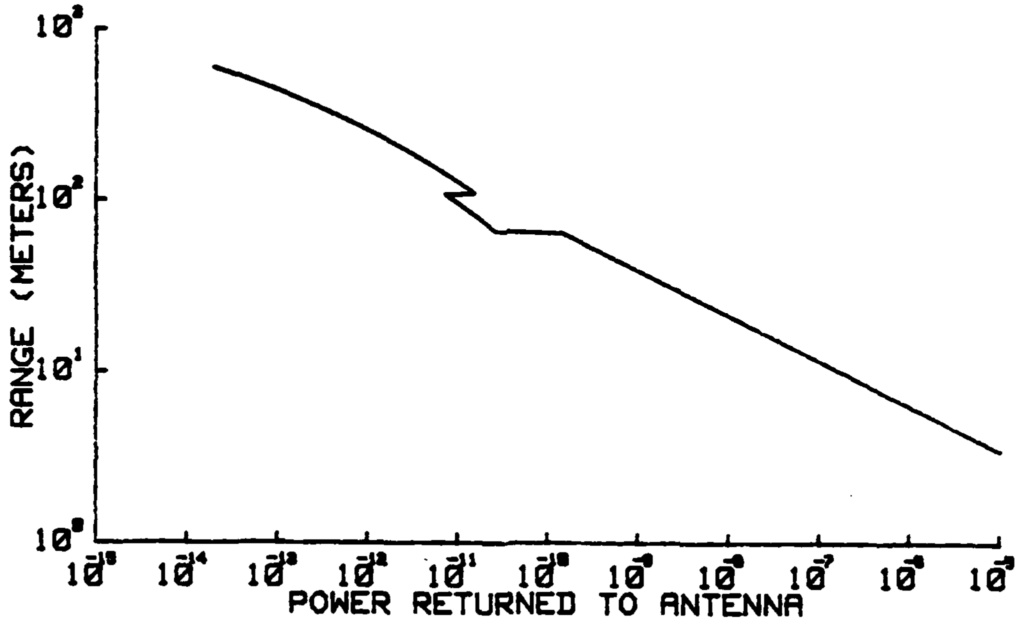

Fig. 28. Range versus Power Returned to the Antenna for C_T^2 Profile 3, Parameters of the Aerovironment Model 300, and S.T.P.

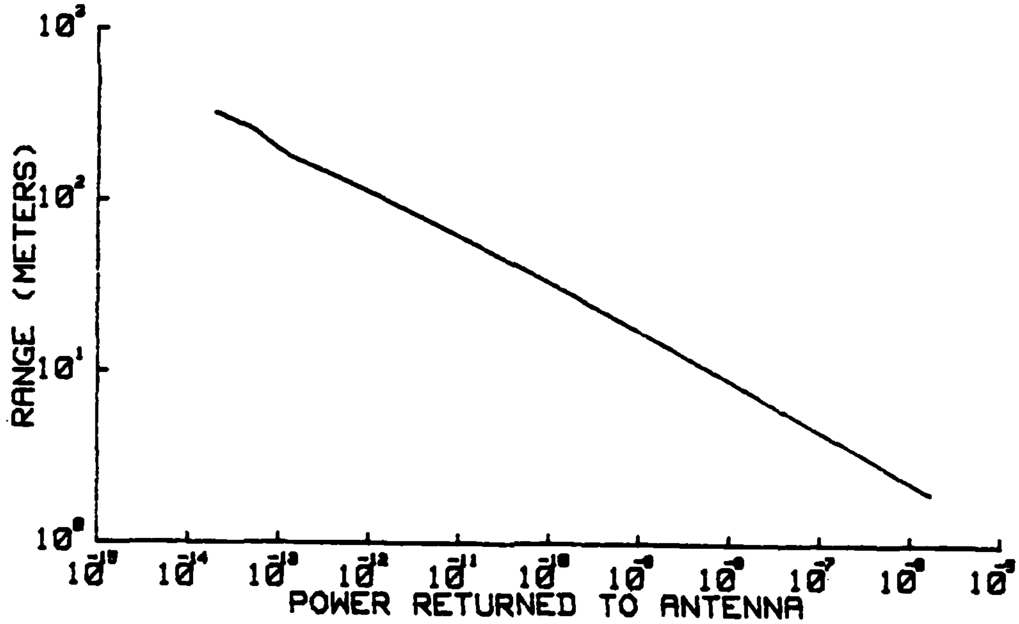

Fig. 29. Range versus Power Returned to the Antenna for C_T^2 Profile 4, Parameters of the Aerovironment Model 300, and S.T.P.

Trends, as input parameters where changed, were also used to check the program output. As the frequency increased, the backscatter of the turbulence in the atmosphere decreased slowly and the absorption of the atmosphere increased rapidly in agreement with Reference 17 [p. I-10].

The calculation for excess attenuation was difficult to check. At ranges of about 400 to 500 meters the excess attenuation of a typical acoustic radar has been found to be about .25, in agreement with the program calculation.

PROGRAM 1

The first program takes atmospheric parameters and the echosounder parameters as input and outputs nine plots. The inputs, by the operator at the keyboard, are:

Atmospheric parameters;

- Atmospheric pressure in millibars,
- The profile of Ct^2 from four options,
- Temperature in degrees Celsius,
- Water-vapor pressure in millibars,

Echosounder data;

- Antenna diameter in meters,
- Frequency of the echosounder in Hertz,
- Power transmitted by the echosounder in Watts, and
- Pulse length of the transmitted acoustic energy.

The program outputs the following plots:

1. Attenuation (1/m) versus water-vapor pressure (mb) for five frequencies at one-third octaves around the input frequency.
2. Attenuation (1/m) versus relative humidity (%) for five frequencies at one-third octaves around the input frequency.
3. Attenuation (1/m) versus water-vapor pressure (mb) for five temperatures at ten degree intervals around the input temperature.
4. Attenuation (1/m) versus relative humidity (%) for five temperatures at ten degree intervals around the input temperature.
5. Range (m) versus excess attenuation.
6. Range (m) versus the temperature structure factor Ct^2.
7. Range (m) versus the velocity structure factor Cv^2.
8. Range (m) versus the acoustic refractive index structure factor Cne^2.
9. Range (m) versus the power backscattered to the echosounder.

All of the programs prompt the operator for inputs and with a series of yes/no questions allows the operator to rerun with the same inputs or change the inputs. Figure 30 is a flow chart of program one and appendix 1 is a copy.

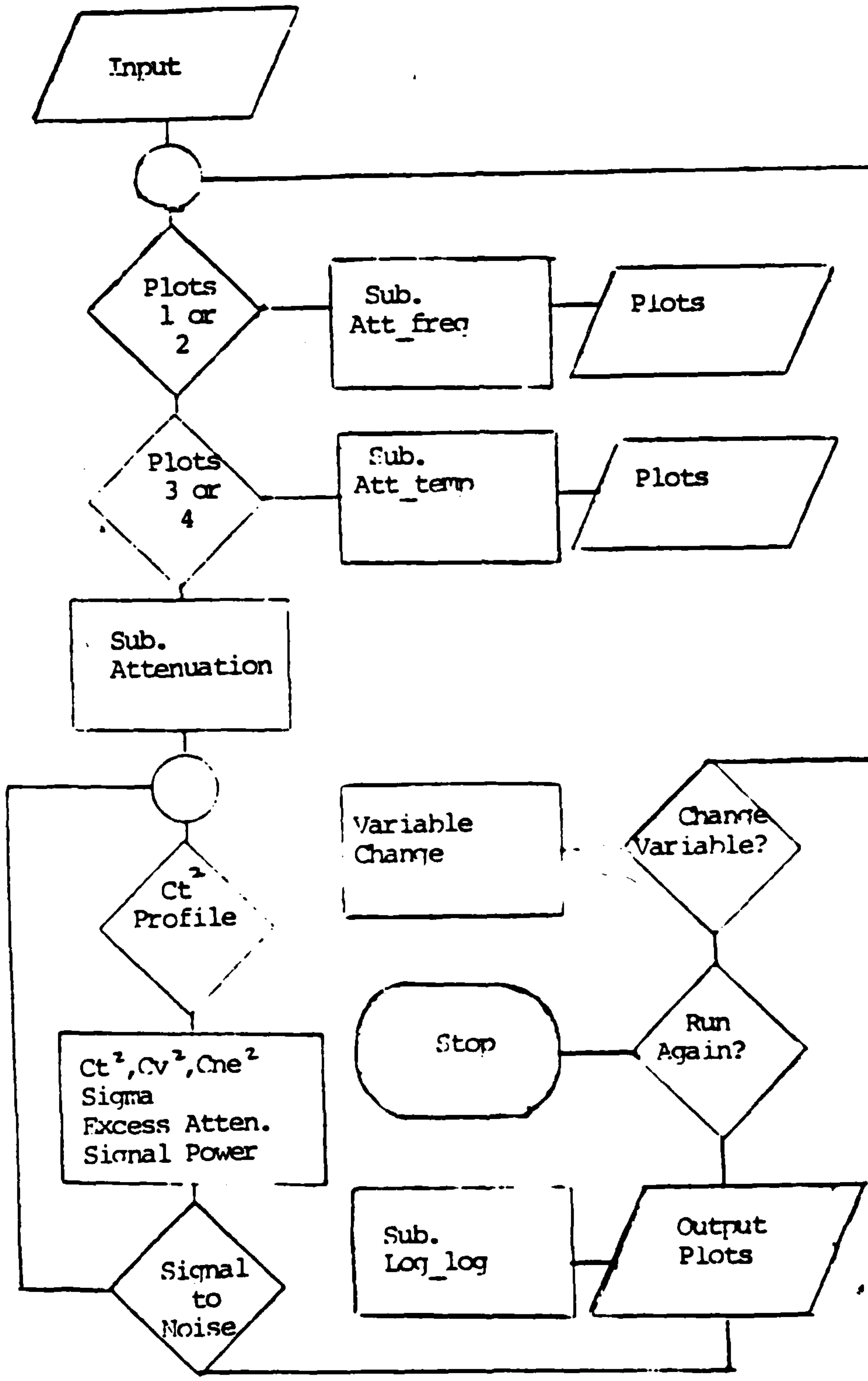

Fig. 30. Flowchart of Computer Model One

Figures 1, 2, 3, 4, 21, 22, 23, 24, 25, 26, 28, and 29 are output plots of program one.

The second program takes the same atmospheric parameters used in the first program. With the exception of the frequency, it takes the same echosounder parameters also. This program outputs a plot of range versus frequency and a plot of range versus excess attenuation for various frequencies. Figure 31 is a flow chart of the program and appendix 2 is a copy. Some output plots of the program are included in the conclusions section.

The third program takes the same atmospheric and echosounder parameters as the first. The program outputs a plot of range as a function of efficiency of the transducer, assuming the same efficiency for transmit and receive. All the other programs and plots in this thesis assume efficiencies of 25%, which is on the high side of typical performance. Appendix 3 is a copy and an output plot is presented in the conclusions section.

The fourth program has the same inputs as the first with the exception of antenna area, which is the dependent variable for the output plot. It plots the range as a function of antenna area for several frequencies and is presented and discussed in the conclusions. The model does not include different efficiencies based on optimum antenna design for different frequencies. The output reflects the

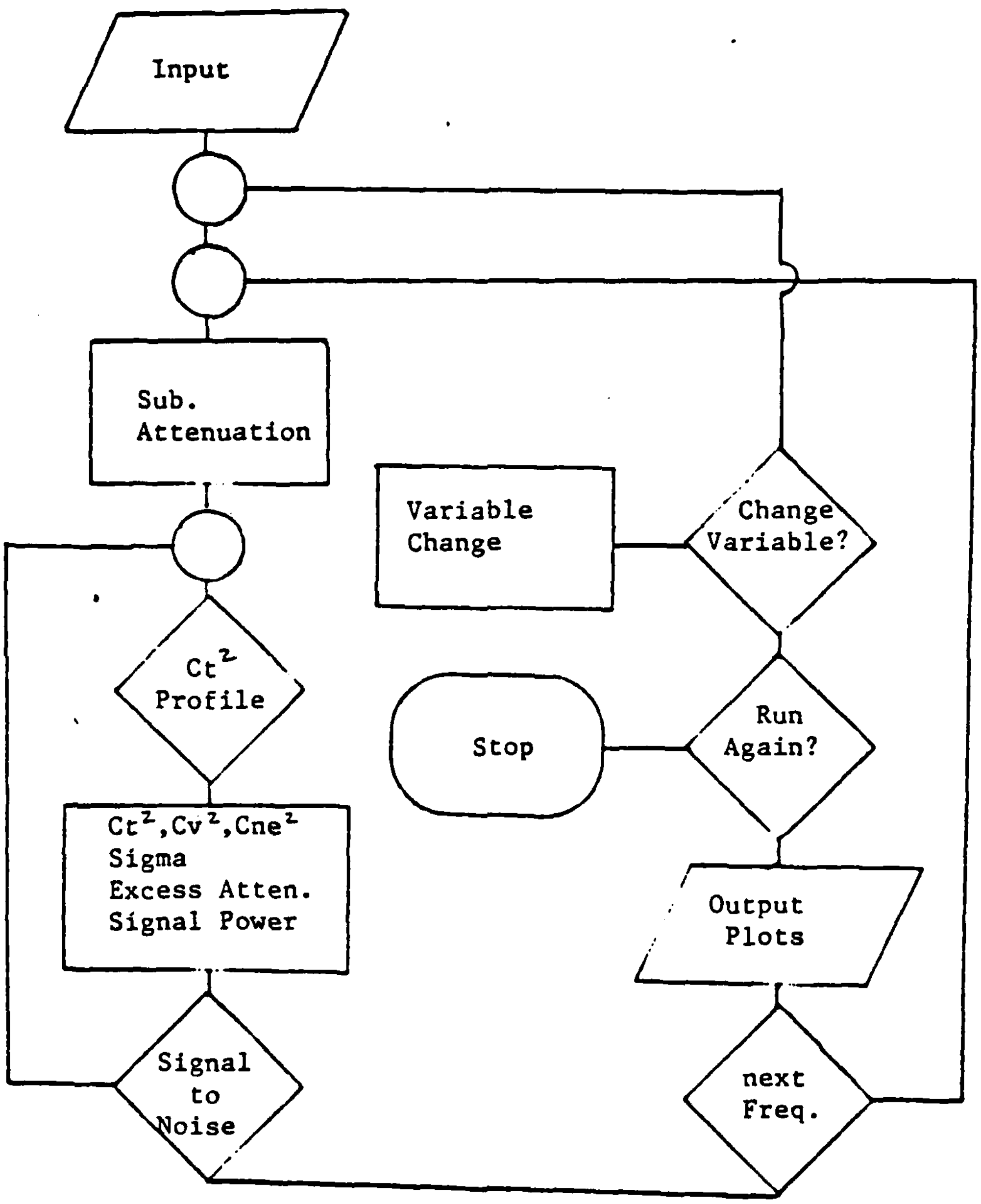

Fig. 31. Flowchart of Computer Model Two.

effect of different antenna diameters on the excess attenuation and the echosonde equation. I am uncertain how much these drive the considerations for optimum antenna design. Appendix 4 is a copy of the program.

The fifth program has the power to the transducer as the dependent variable plotted against range for several frequencies. Appendix 5 is a copy and the output plot is presented and discussed in the conclusions section.

The sixth program has the ambient, atmospheric background noise as the dependent variable. Appendix 6 contains a copy of the program and the output plot is presented and discussed in the conclusions section.

These programs, taken together, allow a parametric analysis of the effect of different parameter changes.

IV CONCLUSIONS

Reference 10 [p. II-1] indicates that as the frequency increases:

1) Background and wind noises decrease except for marked peaks due to fans, etc. This relationship between noise and frequency is not included in the this model.
2) The reflectivity of the turbulence in the atmosphere decreases slowly and the absorption of the atmosphere increases rapidly. The model agrees with this for low values of the water-vapor pressure. The effects of water-vapor pressure on the attenuation are shown in Figures 1 to 4.
3) Wildlife sounds tend to increase with increasing frequency and dominate the background noise at about 3000 Hertz. This effect is not included in the model.
4) The Doppler shift requires the receiver bandwidth to be increased. The model doesn't take this into account. The bandwidth is used to calculate the Johnson noise but Johnson noise is not significant. The noise really should be scaled with frequency to depict the gain in range accurately for lower frequencies.

Transducer efficiencies vary with frequency. This is not included in the model. An increase in efficiency will have a much greater impact on the potential range than increases in, say, power. An increase in efficiency will help both with transmission and return, increasing the transmitted power and the returned electrical signal strength. Figures 32 is a plot of the maximum range for efficiencies of .05 to .5. This figure is the output of program 3. The range increases quickly with improvements in efficiency. The efficiency could be improved by using better designed horns, such as catenoidal or exponential.

Optimum antenna diameters vary with frequency. The output of program 4, Figure 33, demonstrates this effect. Not included are the effects on the antenna effective aperture factor G, except to the extent it may be effected by the excess attenuation. The discontinuities in the curves are due to the discontinuities in the equations for the excess attenuation. For a given frequency, the range increases and then, as antenna diameters increase beyond an optimum, the range decreases. The decrease for larger antenna diameters is the result of the excess attenuation.

One other consideration as to choice of frequency is that the resolution is increased with increasing frequency. A specific need for the echosounder may drive this constraint and is not considered in this model.

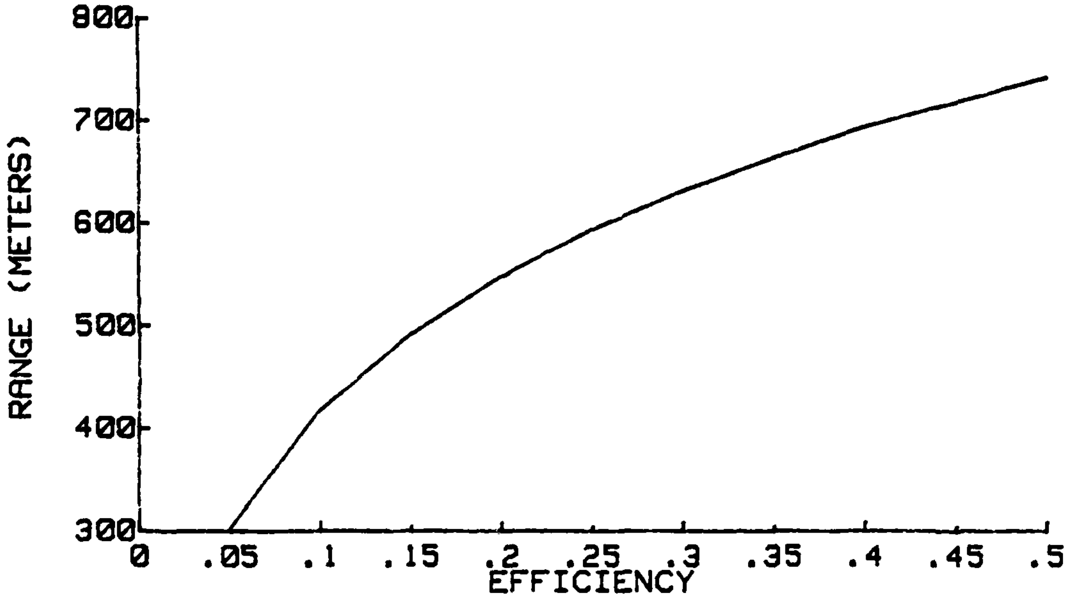

Fig. 32. Range versus Transducer Efficiency for C_T^2 Profile 3, Parameters of the Aerovironment Model 300, and S.T.P.

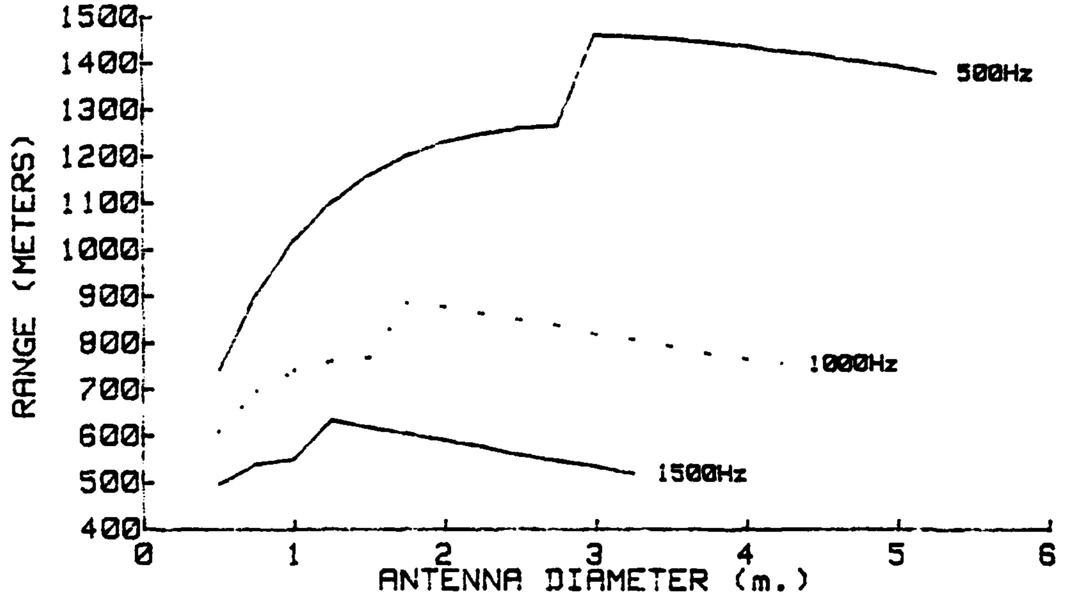

Fig. 33. Range versus Antenna Diameter for C_T^2 Profile 3, Parameters of the Aerovironment Model 300, and S.T.P.

Figure 34 is a plot of range as a function of frequency for an antenna size of 1.5 meters. The water-vapor pressure input was ten millibars. Figure 35 is for the same antenna size but with a water-vapor pressure of 2 millibars. The step in each curve is not a physical effect but rather due to the step of 1.5 in the theoretical equation for the excess attenuation. Figure 1 showed the greater value of the attenuation at around 2 mb. water-vapor pressure for the range of frequencies we are dealing with. These previous two plots demonstrate the effect. Figures 34 and 35 are some of the output plots of program 2. Both figures demonstrate the greater attenuation of the acoustic wave as the frequency increases.

Significant increases in range can be achieved by judicious choice of frequency. Considerations are the water-vapor pressure (Figures 1 to 4), the excess attenuation (Figures 5 to 7), which depends on the antenna diameter (Figure 33), the frequency (Figure 33 to 35), and the anticipated frequency spectrum of the background noise.

Figure 36 models the effect of increasing the transmitted power to increase the range. This is the output plot of program 5. The slope of the curve is not very steep and becomes less so for higher frequencies. A considerable increase in power is required to double the range. Also the model does not include nonlinear transducer effects which

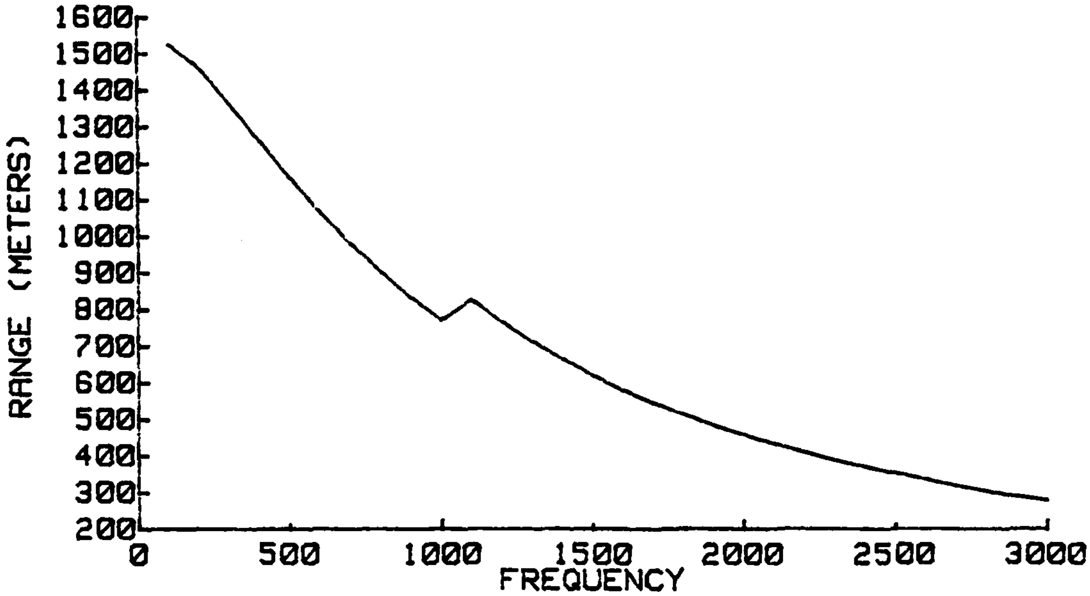

Fig. 34. Range versus Echosounder Frequency for C_t^2 Profile 3, Parameters of the Aerovironment Model 300, and S.T.P.

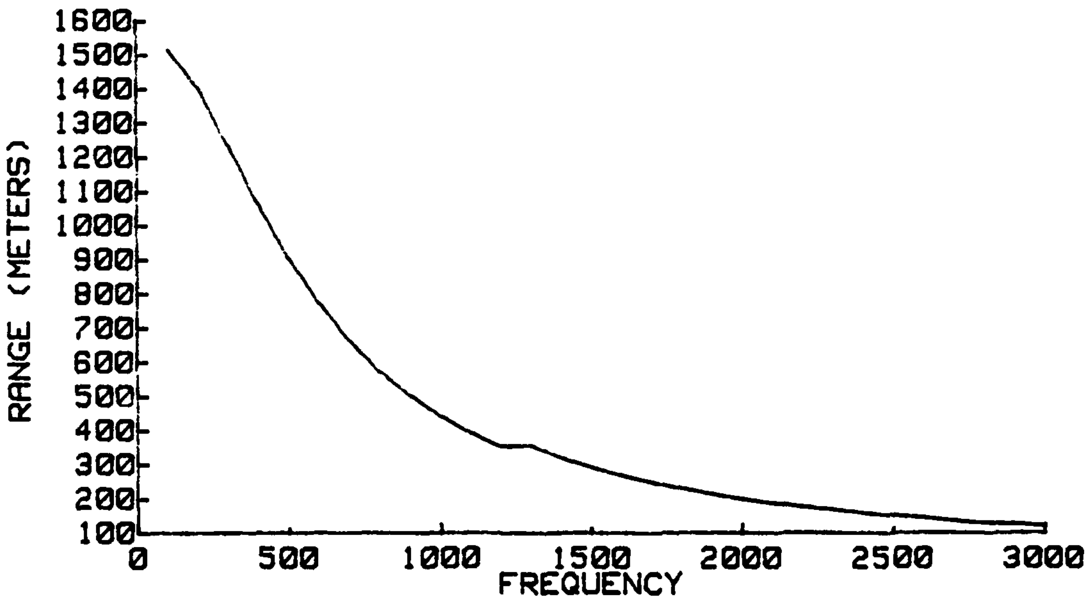

Fig. 35. Range versus Echosounder Frequency for C_T^2 Profile 3, Parameters of the Aerovironment Model 300, and S.T.P. except a Water-vapor Pressure of 2 mb.

arise when the power is increased. Reference 1 [p. 57] points out that at some point the acoustic wave becomes distorted, which implies, from Fourier analysis, there is a flow of energy out of the fundamental frequency into the higher harmonics. Since the higher frequencies are attenuated more quickly we will soon reach a point of saturation, which Brown [Ref. 1 :p 57] called nonlinear saturation to distinguish it from another saturation effect he discusses.

Figure 37 is the output of program 6. This shows the effect of decreasing the ambient background noise level. This decrease in noise might be achieved by using digital processing and fast Fourier transforms to achieve a narrower bandwidth. The bandwidth, and therefore the noise, can be much smaller.

These plots demonstrate which parameter changes might best improve the range of an echosounder, which was one of our goals in this thesis. The modeled performance changes should allow for intelligent decisions of the necessary parameters for the expected uses of the echosounder.

We also sought to explore the ability to use the returned signal to quantify atmospheric parameters accurately at a given range. As can be seen from Figure 27 (the input flow chart), for a single acoustic radar return you could calculate C_T^2 based on an assumed profile of Cv^2.

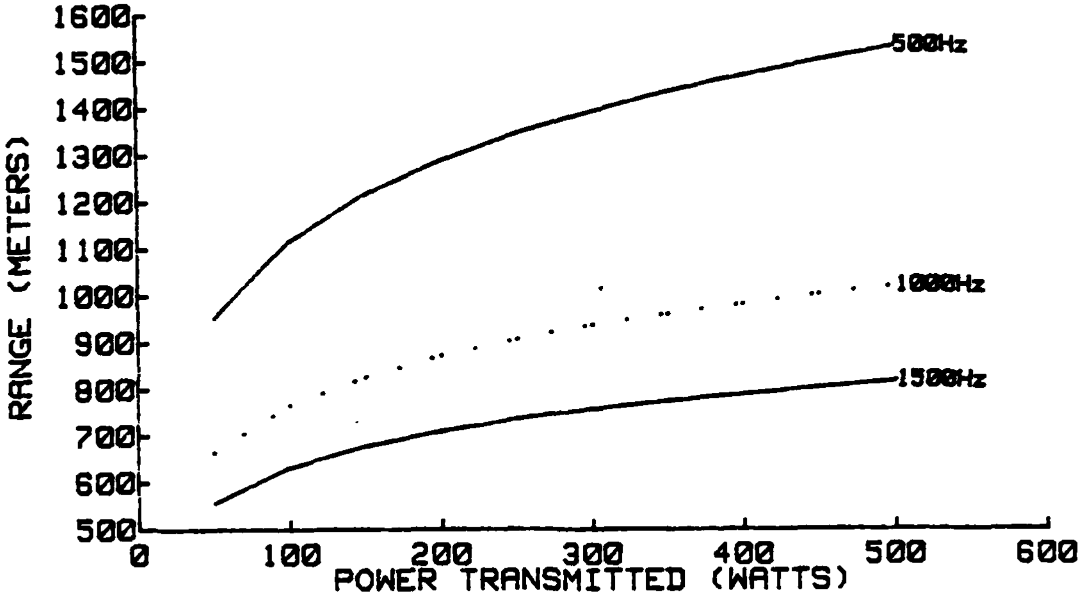

Fig. 36. Range versus Power Transmitted for $C_T{}^2$ Profile 3, Parameters of the Aerovironment Model 300, and S.T.P.

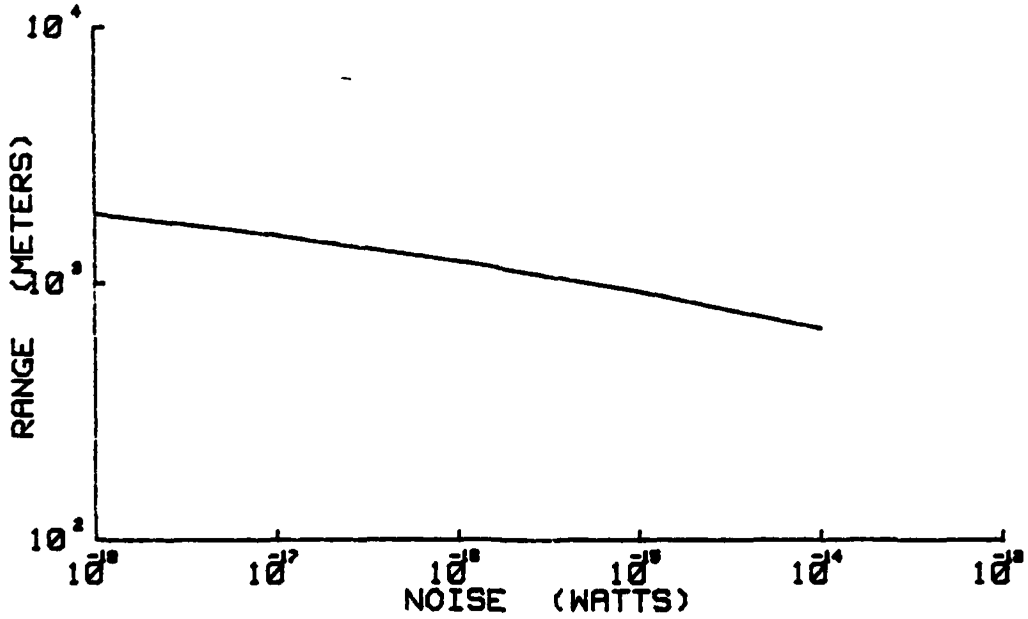

Fig. 37. Range versus Noise Level for $C_T{}^2$ Profile 3, Parameters of the Aerovironment Model 300, and S.T.P.

However this need to assume a Cv^2 profile could be eliminated with the use of two or more echosounders. Reference 11 and many others describe techniques.

Another approach would be to measure the Doppler width. The Doppler width is the spread of frequency around the Doppler shifted frequency. Epsilon and therefore Cv^2 can be related to the Doppler width. With the use of fast Fourier transforms and digital processing Cv^2 and C_T^2 could be measured simultaneously with one echosounder.

Using the returned signal from lesser ranges the energy incident on a given volume could be estimated and the degradation of the return signal could be estimated. In this way the computer program would allow one to essentially boot-strap up to a given range and more accurately depict the atmospheric parameters based on the returned signal.

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APPENDIX A

COMPUTER PROGRAM 1

```
!FULLER, ROBERT      PROG 1
!
!10 SEP 85
!
!
!*******PURPOSE*******
!
!     THIS PROGRAM WILL TAKE PARAMETERS OF AN ECHOSOUNDER AND
!ESTIMATE THE RANGE.  THE FOLLOWING INPUTS ARE REQUIRED:
!
!    ATMOSPHERIC DATA
!    1)ATOMOSPHERIC PRESSURE in millibars
!    2)SELECT ONE OF FOUR ATMOSPHERIC PROFILES FOR THE TEMPERATURE
!      STRUCTURE PROFILE.
!       a)FOR ONE PROFILE THE HEIGHT OF THE INVERSION LAYER IS ALSO INPUT
!    3)TEMPERATURE IN DEGREES CELSIUS
!    4)WATER VAPOR PRESSURE IN millibars
!
!    ECHOSOUNDER DATA
!    5)ANTENNA DIAMETER IN METERS
!    6)FREQUENCY OF ECHOSOUNDER IN Hz
!    7)POWER TRANSMITTED BY ECHOSOUNDER IN WATTS
!    8)PULSE LENGTH OF THE TRANSMITTED ACOUSTIC ENERGY
!
!THE PROGRAM OUTPUTS THE FOLLOWING PLOTS:
!    1)ATTENUATION(1/m.) VERSUS WATER-VAPOR PRESSURE(mb) FOR FIVE
!      FREQUENCIES AT ONE-THIRD OCTIVES AROUND THE INPUT FREQUENCY.
!    2)ATTENUATION(1/m.) VERSUS RELATIVE HUMIDITY(%) FOR FIVE FREQUENCIES
!      AT ONE-THIRD OCTIVES AROUND THE INPUT FREQUENCY.
!    3)ATTENUATION(1/m.) VERSUS WATER-VAPOR PRESSURE(mb) FOR FIVE
!      TEMPERATURES AT TEN DEGREE INTERVALS AROUND THE INPUT TEMPERATURE.
!    4)ATTENUATION(1/m.) VERSUS RELATIVE HUMIDITY(%) FOR FIVE TEMPERATURES
!      AT TEN DEGREE INTERVALS AROUND THE INPUT TEMPERATURE.
!    5)RANGE(m.) VERSUS EXCESS ATTENUATION
!    6)RANGE(m.) VERSUS TEMPERATURE STRUCTURE FACTOR.
!    7)RANGE(m.) VERSUS VELOCITY STRUCTURE FACTOR.
!    8)RANGE(m.) VERSUS ACOUSTIC STRUCTURE FACTOR.
!    9)RANGE(m.) VERSUS BACKSCATTERED TO ECHOSOUNDER.
!
!
!
!*****VARIABLES*****
!
!
!  Again      TEST VALUE IN WHILE LOOP TO DETERMINE IF OPERATOR
!              WISHES TO MAKE ANOUTHER RUN.
!  Ano_change TEST VALUE IN WHILE LOOP TO DETERMINE IF OPERATOR
!              WISHES TO CHANGE THE VALUE OF INPUT DATA BEFORE MAKING
!              ANOUTHER RUN.
!  Ant_area   ECHOSOUNDER ANTENNA AREA CALCULATED FROM INPUT OF
```

```
!               ANTENNA DIAMETER.
!  Ant_diam   INPUT OF ECHOSOUNDER ANTENNA DIAMETER IN METERS.
!  Atom_pres  INPUT OF ATMOSPHERIC PRESSURE IN mb.
!  Atten      ATTENUATION OF ACOUSTIC WAVE.  CALCULATED IN
!               SUBPROGRAM ATTENUATION.
!  Att_freq   VARIABLE USED TO DETERMINE IF OPERATOR
!               WANTS TO PLOT ATTENUATION VERSUS WATER_VAPOR
!               PRESSURE FOR VARIOUS FREQUENCIES AROUND THE INPUT
!               FREQUENCY.  IF SO THEN PLOT IS DONE IN SUBPROGRAM
!               Att_freq.
!  Att_max    VARIABLE IN SUBPROGRAM ATTENUATION.  IT IS THE
!               ATTENUATION AT THE FREQUENCY OF THE MAXIMUM
!               ATTENUATION FOR THE INPUT CONDITIONS.
!  Att_temp   VARIABLE USED TO DETERMINE IF OPERATOR WANTS
!               TO PLOT ATTENUATION VERSUS WATER_VAPOR PRESSURE
!               FOR VARIOUS TEMPERATURE AROUND THE INPUT TEMPERATURE.
!               THE PLOT IS DONE IN THE SUBPROGRAM Att_temp.
!  Bn         BANDWIDTH OF RECEIVER NEEDED TO RECEIVE SIGNALS
!               DOPPLER SHIFFED BY THREE METER PER SECOND
!               VERTICAL VELOCITIES.
!  C          VELOCITY OF SOUND CALCULATION AT ZERO CELSIUS.
!  C1 & C2    VARIABLES USED TO SCALE INVERSION HEIGHT IN
!               TEMPERATURE STRUCTURE PROFILE THREE.
!  C3         CONSTANT USED IN CALCULATION FOR Cte2 PROFILE 4.
!  Cne2(*)    ARRAY OF VALUES OF THE ACOUSTIC REFRACTIVE INDEX
!               PARAMETER.  CALCULATED BASED ON SELECTION OF
!               PROFILE FOR TEMPERATURE STRUCTURE PARAMETER
!               AND ASSUMED PROFILE FOR THE VELOCITY STRUCTURE
!               PARAMETER.
!  Cte2(*)    ARRAY OF VALUES OF THE TEMPERATURE STRUCTURE PARAMETER.
!               THE OPERATOR SELECTS A PROFILE FROM SEVERAL PROVIDED.
!  Cve2(*)    ARRAY OF VALUES OF THE VELOCITY STRUCTURE  PARAMETER.
!               VALUES BASED ON CALCULATION USING ASSUMED DISSAPATION
!               RATE.
!  Dx         STEP SIZE FOR X AXIS FOR VARIOUS PLOTS.
!  Dy         STEP SIZE FOR Y AXIS FOR VARIOUS PLOTS.
!  Epsilon    DISSAPATION RATE USED IN CALCULATION OF Cve2.
!  Et         TRANSMISSION EFFICIENCY OF ECHOSOUNDER.
!  Er         EFFICIENCY OF ECHOSOUNDER WHEN RECEIVING ACOUSTIC
!               BACKSCATTER.
!  Es         SATURATION VAPOR PRESSURE AT GIVEN TEMPERATURE.
!  Exc_att(*) EXCESS "ATTENUATION" AT GIVEN RANGE.
!  F          VARIABLE USED IN SUBPROGRAM ATTENUATION.  IS THE
!               RATIO OF FREQUENCY TO FREQUENCY AT MAXIMUM ATTENUATION.
!  Fmax       FREQUENCY OF MAXIMUM ATTENUATION. USED IN SUBPROGRAM
!               ATTENUATION.
!  Freq       INPUT FREQUENCY OF ECHOSOUNDER.
!  Freq_con   USED TO INSURE VALUE OF FREQUENCY PASSED TO SUBPROGRAM
!               Att_freq WAS NOT CHANGED.
!  G          ANTENNA EFFECTIVE APERATURE FACTOR.
```

```
!  H            VARIABLE USED IN INTEGRATION FOR EXCESS ATTENUATION.
!  I            MAIN INDEX FOR LOOP TO CHECK RETURNED POWER UNTIL
!                POWER WAS LESS THAN MINIMUM DETECTABLE SIGNAL.
!  Interval     MAXIMUM EFFECTIVE-SCATTERING VOLUME THICKNESS.
!  Inver        HEIGHT OF INVERSION LAYER.
!  J            FIRST ORDER INDEX FOR ASSORTED LOOPS.
!  K            WAVENUMBER
!  L            SECOND ORDER INDEX FOR ASSORTED LOOPS.
!  Mess_up      TEST VALUE TO CHECK RESPONSES WHEN OPERATOR IS INPUTTING
!                RESPONSES.
!  N            TEST VALUE IN CALCULATION OF COHERENCE LENTH IN CALCULATION
!                OF EXCESS ATTENUATION.
!  New_va       TEST VALUE IN CHECKING IF OPERATOR WISHES TO CHANGE
!                A VARIABLE BEFORE A NEW RUN.
!  Noise        ASSUMED MINIMUM DETECTABLE SIGNAL.
!  Pow_back(*) POWER BACKSCATTERED FROM GIVEN RANGE.
!  Pow_ret(*)  POWER BACKSCATTERED TO ECHOSOUNDER FROM GIVEN RANGE.
!  Pow_trans    INPUT OF POWER SUPPLIED TO TRANSDUCER OF ECHOSOUNDER.
!  Profile      OPERATOR INPUT OF Ct^2 PROFILE FROM AVAILABLE PROFILES.
!  Pstar        VARIABLE USED IN SUBPROGRAM ATTENUATION FOR INTERMEDIATE
!                CALCULATION.
!  Pulse        TRANSMITTED PULSE LENGTH IN MILLISECONDS.  INPUT BY
!                OPERATOR.
!  R            RANGE FOR INPUT TO INTEGRAL OF EXCESS ATTENUATION.
!  R1           VARIABLE USED IN SCALING INVERSION HEIGHT FOR PROFILE THREE.
!  Range(*)     ARRAY OF RANGE VALUES.
!  Remainder    REMAINDER OF MODULO FUNCTION USED TO DECREES THE
!                NUMBER OF PASSES THROUGH THE INTEGRATION FOR EXCESS
!                ATTENUATION.
!  Rge          VALUE OF RANGE IN INTEGRAL FOR EXCESS ATTENUATION.
!  Rho          CORRELATION LENGTH USED IN CALCULATION OF EXCESS
!                ATTENUATION.
!  Sigma(*)     FRACTION OF ENERGY BACKSCATTERED FROM GIVEN RANGE.
!  Speed_sound SPEED OF SOUND IN AIR AT INPUT TEMPERATURE.
!  Sumpow_back SUM OF THE BACKSCATTERED ENERGY
!  T            INPUT TEMPERATURE IN DEGREES KELVIN.
!  Temp         INPUT TEMPERATURE IN DEGREES CELSIUS.
!  Temp_con     USED TO INSURE VALUE OF TEMPERATURE PASSED TO SUBPROGRAM
!                Att_temp WAS NOT CHANGED.
!  Temp$        VARIABLE STRING USED IN FUNCTION YES.
!
!  Title$       STRING PASSED TO SUBPROGRAM PT FOR TITLE OF PLOT.
!  Tstar        INTERMEDIATE VALUE USED IN CALCULATION OF ATTENUATION
!                IN SUBPROGRAM ATTENUATION.
!  Var          USED TO SELECT THE VARIABLE THE OPERATOR WISHED TO
!                CHANGE BEFORE MAKING ANOTHER RUN.
!  Wat_pres     ATMOSPHERIC WATER PRESSURE IN MILLIBARS.  INPUT BY
!                OPERATOR.
!  X            THIRD ORDER INDEX USED IN VARIOUS LOOPS.
!  X$           STRING PASSED TO FUNCTION YES TO DETERMINE OPERATOR
```

```
!                RESPONSE TO YES OR NO QUESTION.
!  Xlabel$     LABEL ON X AXIS PASSED TO SUBPROGRAM Pt FOR PLOTTING.
!  Xmax        VALUE OF LARGEST VALUE OF X FOR VARIOUS PLOTS.
!  Xmin        VALUE OF SMALLEST VALUE OF X FOR VARIOUS PLOTS.
!  Xrange      VALUE OF RANGE OF X VALUES FOR VARIOUS PLOTS.
!  Xvar(*)     VALUE OF ARRAY OF X VALUES TO BE PLOTTED IN SUBPROGRAM Pt.
!  Ylabel$     LABEL ON Y AXIS PASSED TO SUBPROGRAM Pt FOR PLOTTING.
!  Ymax        LARGEST VALUE OF Y VARIABLE FOR VARIOUS PLOTS.
!  Ymin        SMALLEST VALUE OF Y VARIABLE FOR VARIOUS PLOTS.
!  Yrange      RANGE OF Y VARIABLES FOR VARIOUS PLOTS.
!  Ze          INTERMEDIATE VALUE IN CALCULATION OF EXCESS ATTENUATION.
!
!
!DECLARE VARIABLES
INTEGER I
DIM Pow_back(1500),Pow_ret(1500),Range(1500),Cte2(1500),Sigma(1500)
DIM Cve2(1500),Cne2(1500),Exc_att(1500),Xvar(1500)
DIM Title$[50],Xlabel$[50],Ylabel$[16]
!
PLOTTER IS 705,"HPGL"
LINE TYPE 1
!
!INPUT ATMOSPHERIC DATA
INPUT "ENTER TEMPERATURE IN DEGREES CELCIUS",Temp
INPUT "ENTER ATMOSPHERIC PRESSURE IN MILLIBARS",Atom_pres
INPUT "ENTER WATER VAPOR PRESSURE IN MILLIBARS",Wat_pres
!
!
!INPUT ECHOSOUNDER DATA
INPUT "ENTER FREQUENCY OF ECHOSOUNDER IN HERTZ",Freq
INPUT "ENTER ANTENNA DIAM IN METERS",Ant_diam
INPUT "ENTER ECHOSOUNDER PULSE LENGTH IN MILLISECONDS=",Pulse
INPUT "ENTER POWER TO TRANSMITTER IN WATTS",Pow_trans
Et=.25         !TRANSMIT EFFICIENCY
Er=.25         !RECEIVER EFFICIENCY
G=.40          !ANTENNA EFFECTIVE APERATURE FACTOR
!
!
!SELECT THE PROFILE FOR THE TEMPERATURE STRUCTURE
PRINT "YOU HAVE A CHOICE OF TEMPERATURE STRUCTURE PROFILES"
PRINT "PROFILE TO BE USED."
PRINT "YOUR SELECTIONS ARE"
PRINT "      1      A TEMPERARURE STRUCTURE PROFILE BASED ON DATA AS "
PRINT "             PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398 WHICH "
PRINT "              GIVES A HEIGHT TO THE -1.16 PROFILE"
PRINT " "
PRINT "      2      THE TEMPERATURE STRUCTURE PROFILE ABOVE BUT"
PRINT "             WITH A FACTOR OF TWO TO APPROXIMATE LOOKING"
PRINT "             UP A CONVECTIVE PLUME"
PRINT " "
```

```
PRINT "     3       A TEMPERATURE STRUCTURE PROFILE BASED ON DATA AS"
PRINT "             PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398 FOR"
PRINT "             NIGHT CONDITIONS.  THE DEPENDENCE WITH HEIGHT "
PRINT "             IS EXP(-.001*HEIGHT ABOVE 65 METERS AND HEIGHT"
PRINT "             TO THE -1.46 BELOW 65 METERS"
PRINT " "
PRINT "     4       A TEMPERATURE STRUCTURE PROFILE BASED ON A"
PRINT "              HEIGHT TO THE -4/3 "
!
PRINT " "
PRINT " "
Mess_up=1
WHILE Mess_up=1
     INPUT "ENTER THE DESIRED PROFILE (1 OR 2 OR 3 OR 4)",Profile
     IF Profile=4 THEN
          INPUT "ENTER THE HEIGHT OF THE INVERSION IN METERS",Inver
     END IF
     IF Profile=1 THEN
         Mess_up=0
     ELSE
         IF Profile=2 THEN
              Mess_up=0
         ELSE
              IF Profile=3 THEN
                   Mess_up=0
              ELSE
                   IF Profile=4 THEN
                        Mess_up=0
                   ELSE
                        PRINT Profile," WAS NOT ONE OF THE OPTIONS!!!!"
                        Mess_up=1
                   END IF
              END IF
         END IF
      END IF
END WHILE
OUTPUT KBD;"K";
!
!
Again=1
!INITIALIZE ARRAYS FOR SUCCESSIVE RUNS
WHILE Again=1
  FOR J=1 TO I
     Pow_back(J)=0
     Pow_ret(J)=0
     Range(J)=0
     Cte2(J)=0
     Sigma(J)=0
     Cve2(J)=0
     Cne2(J)=0
```

```
   Exc_att(J)=0
NEXT J
FOR J=1 TO 15
     PRINT " "
NEXT J
PRINT "DO YOU WISH TO SEE A PLOT OF ATTENUATION VERSUS HUMIDITY"
PRINT "FOR VARIOUS FREQUENCIES AROUND THE FREQUENCY YOU INPUT?"
LINPUT "IF YES ENTER Y , IF NO ENTER N",X$
Att_freq=FNYes(X$)
IF Att_freq=1 THEN
     OUTPUT KBD;"K";
     CALL Att_freq(Atom_pres,Freq,Temp)
END IF
OUTPUT KBD;"K";
!
!
FOR J=1 TO 15
     PRINT " "
NEXT J
PRINT "DO YOU WISH TO SEE A PLOT OF ATTENUATION VERSUS HUMIDITY"
PRINT "FOR VARIOUS TEMPERATURES AROUND THE TEMPERATURE YOU INPUT?"
LINPUT "IF YES ENTER Y , IF NO ENTER N",X$
Att_temp=FNYes(X$)
IF Att_temp=1 THEN
     OUTPUT KBD;"K";
     CALL Att_temp(Atom_pres,Freq,Temp)
END IF
OUTPUT KBD;"K";
!
!CONVERT TEMPERATURE TO KELVIN
T=Temp+273
!
!CALCULATE SPEED OF SOUND BASED ON INPUT TEMPERATURE(CELCIUS)
Speed_sound=20.05*(T)^.5
!CALCULATE THE SPEED OF SOUND AT 0 DEGREES CELCIUS
C=20.05*273^.5
!
!CALCULATE THE ATTENUATION COEFFICIENT BASED ON ATMOSPHERIC DATA
!EQUATION IS FROM NEFF 1975
CALL Attenuation(Atom_pres,Atten,Freq,Temp,Wat_pres)
I=1    !INDEX FOR LOOP
Pow_back(0)=0    !INITIALIZE VARIABLE FOR POWER BACKSCATERRED
K=2*PI*Freq/Speed_sound    !WAVENUMBER
Ant_area=PI*(Ant_diam/2)^2   !ANTENNA AREA
Interval=(Speed_sound*Pulse*1.E-3)/2
Bn=2*Freq*(1-1/(6/Speed_sound+1))!BANDWIDTH FOR 3M/S VERTICAL VELOCITIES
Noise=1.38E-23*Bn*(T)+2.E-14!MINIMUM DETECTABLE SIGNAL AS
!     JOHNSON NOISE(NEGLIGABLE)+ ESTIMATED BACKGROUND
!
!CALCULATE RETURNED SIGNAL POWER UNTIL IT IS LESS THAN BACKGROUND.
```

```
Range(0)=0
Sumpow_back=0
REPEAT
   Range(I)=Range(I-1)+2
   SELECT Profile
         CASE 1
         !THIS TEMPERATURE STRUCTURE PROFILE IS BASED UPON DATA
         !AS PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398.
         !WAS FOR MIDDAY AND CLEAR WEATHER ABOVE THE
         !TULAROSA BASIN, NEW MEXICO.
         !AN ADDITONAL FACTOR OF 1.8 WAS INCLUDED AS PER DIFFERENT
         !AVERAGING TIME.
             Cte2(I)=2.12*Range(I)^(-1.16)
         CASE 2
         !THIS TEMPERATURE STRUCTURE PROFILE IS BASED UPON DATA
         !AS PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398.
         !WAS FOR MIDDAY AND CLEAR WEATHER ABOVE THE
         !TULAROSA BASIN, NEW MEXICO.
         !AN ADDITONAL FACTOR OF 1.8 WAS INCLUDED AS PER DIFFERENT
         !AVERAGING TIME AND AN ADDITIONAL FACTOR OF TWO WAS
         !INCLUDED TO APPROXIMATE LOOKING UP A CONVECTIVE PLUME
             Cte2(I)=2*2.12*Range(I)^(-1.16)
         CASE 3
         !THIS TEMPERATURE STRUCTURE PROFILE BASED ON DATA AS"
         !PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398 FOR"
         !NIGHT CONDITIONS.  THE DEPENDENCE WITH HEIGHT "
         !IS EXP(-.001*HEIGHT ABOVE 65 METERS AND HEIGHT"
         !TO THE -1.46 BELOW 65 METERS"
             IF Range(I)<65 THEN
                  Cte2(I)=75.5*Range(I)^(-1.46)
             ELSE
                  Cte2(I)=3.66E-2*EXP(-.001*Range(I))
             END IF
         CASE 4
         !CALCULATE THE TEMPERATURE STRUCTURE FACTOR BASED ON ASSUMPTION
         !    THAT IT'S PROPORTIONAL TO HEIGHT TO THE -4/3 POWER
         !    THAT THE SURFACE VERTICAL HEAT FLUX IS .095 C.m./sec
         !THE DEPENDENCE WITH HEIGHT ABOVE THE INVERSION I PULLED FROM
         !MY LEFT EAR
         !EQUATION FROM NEFF, 1975
         SELECT Range(I)/Inver
             CASE <.9
                  C3=((.024)*(T)^(.667))
                  Cte2(I)=C3*(Range(I))^(-1.33)
             CASE .9 TO 1
                  Cte2(I)=Cte2(I-1)
                  R1=Range(I)
                  C1=Cte2(I)
             CASE 1 TO 1.3
                  Cte2(I)=10^((LGT(C3*Range(I))-LGT(C3*R1))+LGT(C1))
```

```
                R2=Range(I)
                C2=Cte2(I)
            CASE ELSE
                Cte2(I)=C3*(Range(I)^(-1.33)-R2^(-1.33))+C2
        END SELECT
    END SELECT
    !CALCULATE VELOCITY STRUCTURE FACTOR. FORMULA FROM GAYNOR 77
    !AND TETARSKI
    Epsilon=(.2866/Range(I))*(1+.07*(Range(I))^(.6))^(1.5)
    Cve2(I)=2*Epsilon^(.667)
    !CALCULATE ACOUSTIC REFRACTIVE INDEX STRUCTURE FACTOR.
    !FORMULA FROM TETARSKI 1961
    Cne2(I)=(Cte2(I)/(2.98E+5))+(Cve2(I)/(C*C))
    !CALCULATE THE FRACTION OF POWER BACKSCATTERED FROM INTERVAL.
    !EQUATION FROM NEFF, 1975
    Sigma(I)=(.0039*(K^(1/3))*Cte2(I))/(T)^2
    !
    !CALCULATE THE EXCESS ATTENUATION.  EQUATION FROM CLIFFORD, 1980
    !THE EXCESS ATTENUATION IS Exc_att(I)
    !THE MODULO STRUCTURE IS TO SKIP SOME OF THE INTEGRALS ONCE THE
    !RESOLUTION IS LESS IMPORTANT.
    IF I<50 THEN
        Remainder=0
    ELSE
        IF I<150 THEN
            Remainder=Range(I) MODULO 10
        ELSE
            Remainder=Range(I) MODULO 20
        END IF
    END IF
    IF Remainder=0 THEN
        Rho=0
        L=0
        H=0
        Rge=Range(I)     !CONSTANT IN INTEGRAL
        R=0
        FOR J=0 TO 2*I
                F=Cne2(INT(J/2+1))
                F=F*(1-R/(Rge)^(1.67)+(R/(Rge))^(1.67))
                IF J>0 THEN
                    IF J<2*I THEN
                        IF INT(J/2)=J/2 THEN
                            L=L+F
                            F=0
                        ELSE
                            H=H+F
                            F=0
                        END IF
                    END IF
                END IF
```

```
                    Rho=Rho+F
                    R=R+1
          NEXT J
          Rho=Rho+4*L+2*H
          Rho=(((Rho*.33)*K*K*1.46)^(-.6))
          N=(Ant_diam/Rho)^2
          IF N<=1 THEN
               Ze=1/(1+N)
          ELSE
               Ze=1.5/(1+N)
               !STEP OF 1.5==>SEE CLIFFORD 1980
          END IF
          Exc_att(I)=Ze*Ze
     ELSE
          Exc_att(I)=Exc_att(I-1)
     END IF
     !
     !CALCULATE THE POWER BACKSCATTERED
     Pow_back(I)=(Pow_trans*Et-Sumpow_back)*EXP(-Atten*Range(I))
     Pow_back(I)=Pow_back(I)*Interval*Exc_att(I)*Sigma(I)
     Sumpow_back=Sumpow_back+Pow_back(I)
     !CALCULATE THE POWER BACKSCATTERED TO THE ANTENNA
     !TWO WAY PATH ATTENUATION ACCOUNTED FOR ABOVE.
     Pow_ret(I)=Pow_back(I)*EXP(-Atten*Range(I))*Ant_area*G*Er/Range(I)^2
     PRINT "RANGE=",Range(I)
     PRINT "POWER RETURNED=",Pow_ret(I)
     I=I+1
UNTIL Pow_ret(I-1)>0 AND Pow_ret(I-1)<=Noise
!
!
OUTPUT KBD;"K";
!
PRINT "INPUT CONDITIONS"
!
PRINT " "
PRINT USING "K";"TEMPERATURE=                  ",Temp,"CELCIUS"
PRINT USING "K";"ATMOSPHERIC PRESSURE=         ",Atom_pres,"mb"
PRINT USING "K";"WATER VAPOR PRESSURE=         ",Wat_pres,"mb"
PRINT USING "K";"PULSE LENGTH=                 ",Pulse,"ms"
PRINT USING "K";"TRANSMITTED FREQUENCY=        ",Freq," Hz"
PRINT USING "K";"ANTENNA DIAMETER=             ",Ant_diam," m."
PRINT USING "K";"POWER TRANSMITTED=            ",Pow_trans," WATTS"
PRINT "TEMPERATURE STRUCTURE PROFILE USED ",Profile
IF Profile=4 THEN
   PRINT "INVERSION HEIGHT ",Inver
END IF
SELECT Profile
   CASE 1
       PRINT "     1       A TEMPERARURE STRUCTURE PROFILE BASED ON DATA"
       PRINT "             AS PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398 "
```

```
        PRINT "                WHICH GIVES A HEIGHT TO THE -1.16 PROFILE"
    CASE 2
        PRINT "       2        A TEMPERARURE STRUCTURE PROFILE BASED ON DATA"
        PRINT "                AS PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398 "
        PRINT "                WHICH GIVES A HEIGHT TO THE -1.16 PROFILE"
        PRINT "                BUT WITH A FACTOR OF TWO TO APPROXIMATE"
        PRINT "                LOOKING UP A CONVECTIVE PLUME"
    CASE 3
        PRINT "       3        A TEMPERATURE STRUCTURE PROFILE BASED ON DATA"
        PRINT "                AS PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398"
        PRINT "                FOR NIGHT CONDITIONS.  THE DEPENDENCE WITH"
        PRINT "                HEIGHT IS EXP(-.001*HEIGHT ABOVE 65 METERS"
        PRINT "                AND HEIGHT TO THE -1.46 BELOW 65 METERS"
    CASE 4
        PRINT "       4        A TEMPERATURE STRUCTURE PROFILE BASED ON A"
        PRINT "                 HEIGHT TO THE -4/3 "
END SELECT
!
PRINT USING "K";"THE MINIMUM DETECTABLE SIGNAL WAS SET AT",Noise,"WATTS"
!
PRINT " "
PRINT "OUTPUT CONDITIONS"
!
PRINT USING "K";"RANGE=",Range(I-2)," m."
!
PRINT "HIT CONTINUE TO CONTINUE"
PAUSE
OUTPUT KBD;"K";
PRINT "THE FOLLOWING GRAPHS WILL NOW BE PLOTTED WITH RANGE VERSUS"
PRINT "EXCESS ATTENUATION"
PRINT "CTE2 (TEMPERATURE STRUCTURE PARAMETER)"
PRINT "CVE2 (VELOCITY STRUCTURE PARAMETER)"
PRINT "CNE2 (ACOUSTIC REFRACTIVE INDEX STRUCTURE PARAMETER)"
PRINT "POWER RETURNED"
PRINT "WHEN YOU ARE READY FOR THE FIRST GRAPH HIT CONTINUE"
PAUSE
OUTPUT KBD;"K";
!
GRAPHICS ON
VIEWPORT 15,120,10,70
!
!
!PLOT RANGE VERSUS EXCESS ATTENUATION
Xmin=0
Xmax=1
Ymin=0
IF Range(I-2)<=1000 THEN
   Ymax=3
ELSE
   Ymax=4
```

```
END IF
Dx=.1
Dy=1
Xrange=Xmax-Xmin
Yrange=Ymax-Ymin
WINDOW Xmin,Xmax,Ymin,Ymax
AXES Dx,Dy,Xmin,Ymin,1,1
CLIP OFF
!
!LABEL PLOT
CSIZE 4,.6
LDIR 0
LORG 5
MOVE .5,Ymax*1.1
LABEL "RANGE VERSUS EXCESS ATTENUATION"
!LABEL HORIZONTAL AXES
LDIR 0
LORG 5
FOR J=0 TO Xmax STEP Dx
   MOVE J,-.1*Dy
   LABEL J
NEXT J
MOVE .5*Xrange,-.3*Dy
CSIZE 4,.6
LABEL "EXCESS ATTENUATION"
!LABEL VERTICAL AXES
LORG 8
FOR J=0 TO Ymax STEP Dy
   CSIZE 4,.6
   MOVE -.3*Dx,J
   LABEL "10"
   CSIZE 2
   MOVE -.1*Dx,J+.05*Dy
   LABEL USING "K";J
NEXT J
LDIR PI/2
LORG 6
MOVE -Dx,.5*Yrange
CSIZE 4,.6
LABEL "RANGE (METERS)"
CLIP ON
FOR J=1 TO I-1
   PLOT Exc_att(J),LGT(Range(J))
NEXT J
PRINT "HIT CONTINUE FOR NEXT PLOT"
!
!
!PLOT RANGE VERSUS TEMPERATURE STRUCTURE PARAMETER
PAUSE
GCLEAR
```

```
!
IF Range(I-2)<=1000 THEN
   Xmin=-4
   Ymax=3
ELSE
   Xmin=-5
   Ymax=4
END IF
Xmax=0
Ymin=0
Title$="RANGE vs TEMPERATURE STRUCTURE PARAMETER"
Xlabel$="TEMPERATURE STRUCTURE PARAMETER"
Ylabel$="RANGE (METERS)"
CALL Log_log(Xmin,Xmax,Ymin,Ymax,Cte2(*),I-1,Range(*),I-1,Title$,Xlabel$
l$)
!
!
!PLOT RANGE VERSUS VELOCITY STRUCTURE PARAMETER
PAUSE
GCLEAR
!
Xmin=-2
Xmax=0
Ymin=0
IF Range(I-2)<=1000 THEN
   Ymax=3
ELSE
   Ymax=4
END IF
Title$="RANGE VERSUS VELOCITY STRUCTURE PARAMETER"
Xlabel$="VELOCITY STRUCTURE PARAMETER"
CALL Log_log(Xmin,Xmax,Ymin,Ymax,Cve2(*),I-1,Range(*),I-1,Title$,Xlabel$
el$)
!
!
!PLOT RANGE VERSUS ACOUSTIC REFRACTIVE INDEX STRUCTURE PARAMETER
PAUSE
GCLEAR
Xmin=-7
Xmax=-5
Ymin=0
IF Range(I-2)<=1000 THEN
   Ymax=3
ELSE
   Ymax=4
END IF
Title$="RANGE vs ACOUSTIC INDEX STRUCTURE PARAMETER"
Xlabel$="ACOUSTIC REFRACTIVE INDEX STRUCTURE PARAMETER"
CALL Log_log(Xmin,Xmax,Ymin,Ymax,Cne2(*),I-1,Range(*),I-1,Title$,Xlabel$
el$)
```

```
!
!
!PLOT RANGE VERSUS POWER RETURNED TO ANTENNA
PAUSE
GCLEAR
IF Range(I-2)<=1000 THEN
   Xmin=-15
   Xmax=-5
   Ymax=3
ELSE
   Xmin=-17
   Xmax=-4
   Ymax=4
END IF
Ymin=0
Title$="RANGE VERSUS POWER RETURNED TO ANTENNA"
Xlabel$="POWER RETURNED TO ANTENNA"
Ylabel$="RANGE (METERS)"
CALL Log_log(Xmin,Xmax,Ymin,Ymax,Pow_ret(*),I-1,Range(*),I-1,Title$,Xlab
Ylabel$)
PAUSE
GCLEAR
!
!
!
LINPUT "WOULD YOU LIKE TO MAKE ANOTHER RUN (ENTER Y OR N)?",X$
Again=FNYes(X$)
Mess_up=1
WHILE Mess_up=1
 SELECT Again
   CASE 1
       LINPUT "WOULD YOU LIKE TO CHANGE A VARIABLE (ENTER Y OR N)?",X$
        New_va=FNYes(X$)
        Ano_change=1
        WHILE Ano_change=1
          SELECT New_va
             CASE 1
              PRINT "       VARIABLE            CURRENT VALUE"
              PRINT USING "K";"1  TEMPERATURE          ",Temp,"CELSIUS"
              PRINT USING "K";"2  ATOMOSPHERIC PRESSURE ",Atom_pres,"mb"
              PRINT USING "K";"3  WATER VAPOR PRESSURE ",Wat_pres,"mb"
              PRINT " "
              PRINT USING "K";"4  FREQUENCY OF ECHOSOUNDER ",Freq," Hz"
              PRINT USING "K";"5  ANTENNA DIAMETER      ",Ant_diam," m."
              PRINT USING "K";"6  PULSE LENGTH          ",Pulse," ms"
              PRINT USING "K";"7  POWER TRANSMITTED ",Pow_trans," WATTS"
              PRINT USING "K";"8  ATMOSPHERIC PROFILE  ",Profile
              PRINT " "
              PRINT "ENTER THE NUMBER OF THE VARIABLE YOU WISH TO"
              PRINT "CHANGE"
```

```
                INPUT Var
                SELECT Var
                         CASE 1
                            INPUT "TEMPERATURE=",Temp
                         CASE 2
                            INPUT "ATMOSPHERIC PRESSURE IN mb=",Atom_pres
                         CASE 3
                            INPUT "WATER VAPOR PRESSURE IN mb=",Wat_pres
                         CASE 4
                            INPUT "FREQUENCY IN Hz=",Freq
                         CASE 5
                            INPUT "ANTENNA DIAMETER IN m.=",Ant_diam
                         CASE 6
                            INPUT "PULSE LENGTH IN ms=",Pulse
                         CASE 7
                            INPUT "POWER TRANSMITTED IN WATTS=",Pow_trans
                         CASE 8
                           PRINT " 1  ==> Ct^2 PROFILE OF Z^(-1.16)"
                           PRINT "         FROM WALTERS/KUNDEL 1981"
                           PRINT " 2  ==> SAME AS ONE BUT WITH FACTOR"
                           PRINT "         OF TWO TO APPROXIMATE LOOKING"
                           PRINT "         UP A CONVECTIVE PLUME"
                           PRINT " 3  ==> Ct^2 PROFILE OF EXP(-.001*Z)"
                           PRINT "         FROM WALTERS/KUNDEL 1981."
                           PRINT " 4  ==> CT^2 PROFILE OF Z^(-4/3)"
                           INPUT "ENTER NUMBER OF DESIRED PROFILE",Profile
                           IF Profile=4 THEN
                            INPUT "HEIGHT OF INVERSION IN METERS=",Inver
                           END IF
                         CASE ELSE
                           PRINT Var,"IS NOT ONE OF THE OPTIONS"
                    END SELECT
                    LINPUT "MADE ANOTHER CHANGE(ENTER Y OR N)?",X$
                    New_va=FNYes(X$)
                    Mess_up=2
               CASE 2
                    Mess_up=2
                    Ano_change=2
               CASE ELSE
                    PRINT "YOUR CHOICES WHERE Y OR N !!!!!"
                    Ano_change=1
                    LINPUT "CHANGE A VARIABLE (ENTER Y OR N)?",X$
                    New_va=FNYes(X$)
           END SELECT
         END WHILE
     CASE 2
         Mess_up=2
     CASE ELSE
         PRINT "YOUR CHOICES WHERE Y OR N  !!!!!!"
         Mess_up=1
```

```
        LINPUT "MAKE ANOTHER RUN (ENTER Y OR N)?",X$
        Again=FNYes(X$)
  END SELECT
 END WHILE
END WHILE
PRINT "THAT'S ALL, FOLKS"
end
!
!
!CALCULTE THE ATTENUATION
sub Attenuation(Atom_pres,Atten,Freq,Temp,Wat_pres)
!THIS SUBPROGRAM CALCULATES THE ATTENUATION OF SOUND
!IN AIR BASED UPON EQUATIONS IN NEFF 1975
!
!   INPUT   ATMOSPHERIC PRESSURE IN MILLIBARS
!           FREQUENCY OF SOUND WAVE IN HERTZ
!           TEMPERATURE IN DEGREES CELCIUS
!           WATER-VAPOR PRESSURE IN MILLIBARS
!
!   OUTPUT  ATTENUATION IN 1/METERS
!
!VARIABLES
!  Atom_pres  INPUT OF ATMOSPHERIC PRESSURE IN mb.
!  Atten      ATTENUATION OF ACOUSTIC WAVE.  CALCULATED IN
!              SUBPROGRAM ATTENUATION.
!  Att_max    VARIABLE IN SUBPROGRAM ATTENUATION.  IT IS THE
!              ATTENUATION AT THE FREQUENCY OF THE MAXIMUM
!              ATTENUATION FOR THE INPUT CONDITIONS.
!  F          VARIABLE USED IN SUBPROGRAM ATTENUATION.  IS THE
!              RATIO OF FREQUENCY TO FREQUENCY AT MAXIMUM ATTENUATION.
!  Fmax       FREQUENCY OF MAXIMUM ATTENUATION. USED IN SUBPROGRAM
!              ATTENUATION.
!  Freq       INPUT FREQUENCY OF ECHOSOUNDER.
!  H          VARIABLE USED IN INTEGRATION FOR EXCESS ATTENUATION.
!  Pstar      VARIABLE USED IN SUBPROGRAM ATTENUATION FOR INTERMEDIATE
!              CALCULATION.
!  Temp       INPUT TEMPERATURE IN DEGREES CELSIUS.
!  Tstar      INTERMEDIATE VALUE USED IN CALCULATION OF ATTENUATION
!              IN SUBPROGRAM ATTENUATION.
!  Wat_pres   ATMOSPHERIC WATER PRESSURE IN MILLIBARS.  INPUT BY
!              OPERATOR.
H=100*Wat_pres/Atom_pres
Tstar=(1.8*Temp+492)/519
Pstar=Atom_pres/1014
Fmax=(10+6600*H+44400*H*H)*Pstar/Tstar^.8
Att_max=.0078*Fmax*Tstar^(-2.5)*EXP(7.77*(1-1/Tstar))
F=Freq/Fmax
Atten=(Att_max/304.8)*((.18*F)^2+(2*F*F/(1+F*F))^2)^.5
Atten=(Atten+1.74E-10*Freq*Freq)/4.35
SUBEND
```

```
!
def FNYes(X$)
!THIS FUNCTION INTERPRETS THE OPERATORS RESPONSES TO YES NO QUESTIONS
!
!    INPUT      X$
!
!    OUTPUT     FNYes
!VARIABLES
!  Temp$       VARIABLE STRING USED IN FUNCTION YES.
!  X$          STRING PASSED TO FUNCTION YES TO DETERMINE OPERATOR
!               RESPONSE TO YES OR NO QUESTION.
     DIM Temp$[1]
     Temp$[1,1]=TRIM$(X$)
     SELECT Temp$
     CASE "Y","y"
          RETURN 1
     CASE "N","n"
          RETURN 2
     CASE " "
          RETURN 1
     CASE ELSE
          RETURN -2
     END SELECT
FNEND
!
sub Att_freq(Atom_pres,Freq,Temp)
!
!     THIS SUBPROGRAM PLOTS THE ATTENUATION OF SOUND VERSUS WATER-
!VAPOR PRESSURE FOR FIVE DIFFERENT FREQUENCIES AT 1/3 OCTIVE
!INTERVALS AROUND THE INPUT FREQUENCY.
!
!     INPUT   ATOMOSPHERIC PRESSURE IN MILLIBARS
!             FREQUENCY IN HERTZ
!             TEMPERATURE IN CELCIUS
!
!     OUTPUT  PLOT OF ATTENUATION VERSUS WATER-VAPOR PRESSURE
!
!VARIABLES
!  Atom_pres  INPUT OF ATMOSPHERIC PRESSURE IN mb.
!  Atten      ATTENUATION OF ACOUSTIC WAVE.  CALCULATED IN
!              SUBPROGRAM ATTENUATION.
!  Att_freq   VARIABLE USED TO DETERMINE IF OPERATOR
!              WANTS TO PLOT ATTENUATION VERSUS WATER_VAPOR
!              PRESSURE FOR VARIOUS FREQUENCIES AROUND THE INPUT
!              FREQUENCY.  IF SO THEN PLOT IS DONE IN SUBPROGRAM
!              Att_freq.
!  Es         SATURATION VAPOR PRESSURE AT GIVEN TEMPERATURE.
!  Freq       INPUT FREQUENCY OF ECHOSOUNDER.
!  Freq_con   USED TO INSURE VALUE OF FREQUENCY PASSED TO SUBPROGRAM
!              Att_freq WAS NOT CHANGED.
```

```
! J          FIRST ORDER INDEX FOR ASSORTED LOOPS.
! L          SECOND ORDER INDEX FOR ASSORTED LOOPS.
! Temp       INPUT TEMPERATURE IN DEGREES CELSIUS.
! Temp_con   USED TO INSURE VALUE OF TEMPERATURE PASSED TO SUBPROGRAM
! Wat_pres   ATMOSPHERIC WATER PRESSURE IN MILLIBARS.  INPUT BY
!             OPERATOR.
! X          THIRD ORDER INDEX USED IN VARIOUS LOOPS.
! X$         STRING PASSED TO FUNCTION YES TO DETERMINE OPERATOR
!             RESPONSE TO YES OR NO QUESTION.
! Ymax       LARGEST VALUE OF Y VARIABLE FOR VARIOUS PLOTS.
!
Freq_con=Freq
Temp_con=Temp
Ymax=0
Freq=DROUND(Freq*2^(2/3),3)
FOR J=0 TO 4 STEP .1
     Wat_pres=J
     CALL Attenuation(Atom_pres,Atten,Freq,Temp,Wat_pres)
     IF Atten>Ymax THEN
          Ymax=Atten
     END IF
NEXT J
Ymax=PROUND(Ymax+.005,-2)
GRAPHICS ON
VIEWPORT 15,120,10,70
WINDOW 0,15,0,Ymax
AXES .5,.005,0,0,2,2
CLIP OFF
!LABEL PLOT
CSIZE 4,.6
LDIR 0
MOVE 7.5,Ymax*1.1
LORG 5
LABEL "ATTENUATION VERSUS WATER-VAPOR PRESSURE"
CSIZE 4,.6
!LABEL HORIZONTAL AXES
LDIR 0
LORG 6
FOR J=0 TO 15
     MOVE J,0
     LABEL J
NEXT J
MOVE 7.5,-Ymax*.1
CSIZE 4,.6
LABEL "WATER-VAPOR PRESSURE   mb"
!LABEL VERTICAL AXES
LORG 8
CSIZE 4,.6
FOR J=0 TO Ymax STEP .01
     MOVE .25,J
```

```
     LABEL J
NEXT J
LDIR PI/2
LORG 6
MOVE -2,Ymax*.5
CSIZE 4,.6
LABEL "ATTENUATION   1/m"
!PRINT INPUT CONDITIONS
LDIR 0
LORG 1
MOVE 5.5,Ymax
CSIZE 4,.6
LABEL USING "K";"ATMOSPHERIC PRESSURE=",Atom_pres," mb"
MOVE 5.5,Ymax*.95
CSIZE 4,.6
LABEL USING "K";"TEMPERATURE=",Temp," CELSIUS"
J=0
FOR L=1 TO 5
     FOR X=0. TO 6.5+J STEP .05
          Wat_pres=X
          CALL Attenuation(Atom_pres,Atten,Freq,Temp,Wat_pres)
          IF INT(L/2)=L/2 THEN
               LINE TYPE 2
          ELSE
               LINE TYPE 1
          END IF
          PLOT X,Atten
     NEXT X
     LDIR 0
     LORG 2
     CSIZE 3,.6
     MOVE X,Atten
     LINE TYPE 1
     LABEL USING "K";Freq,"Hz"
     Freq=DROUND(Freq*2^(-1/3),3)
     J=J+1.5
NEXT L
!
PRINT "HIT CONTINUE TO CONTINUE"
PAUSE
GCLEAR
FOR J=0 TO 15
     PRINT " "
NEXT J
PRINT "WOULD YOU LIKE TO SEE THE SAME PLOT ONLY"
PRINT "WITH ATTENUATION VERSUS RELATIVE HUMIDITY?"
LINPUT "IF YES ENTER Y, ELSE ENTER N",X$
Att_freq=FNYes(X$)
IF Att_freq=1 THEN
   OUTPUT KBD;"K";
```

```
WINDOW 0,100,0,Ymax
CLIP ON
AXES 5,.005,0,0,2,2
CLIP OFF
!LABEL PLOT
CSIZE 4,.6
LDIR 0
MOVE 50,Ymax*1.1
LORG 5
LABEL "ATTENUATION VERSUS RELATIVE HUMIDITY"
CSIZE 4,.6
!LABEL HORIZONTAL AXES
LDIR 0
LORG 6
FOR J=0 TO 100 STEP 10
  MOVE J,0
  LABEL J
NEXT J
MOVE 50,-Ymax*.1
CSIZE 4,.6
LABEL "RELATIVE HUMIDITY   %"
!LABEL VERTICAL AXES
LORG 8
CSIZE 4,.6
FOR J=0 TO Ymax STEP .01
  MOVE 1,J
  LABEL J
NEXT J
LDIR PI/2
LORG 6
MOVE -15,Ymax*.5
CSIZE 4,.6
LABEL "ATTENUATION   1/m"
!PRINT INPUT CONDITIONS
LDIR 0
LORG 1
MOVE 40,Ymax
CSIZE 4,.6
LABEL USING "K";"ATMOSPHERIC PRESSURE=",Atom_pres," mb"
MOVE 40,Ymax*.95
CSIZE 4,.6
LABEL USING "K";"TEMPERATURE=",Temp," CELSIUS"
CLIP ON
T=Temp+273
Es=10^(9.4-2353/T)
J=0
Freq=DROUND(Freq_con*2^(-2/3),3)
FOR L=1 TO 5
  FOR X=0. TO 40+J STEP .5
       Wat_pres=Es*Atom_pres*X/((Atom_pres-Es*(1+X/100))*100)
```

```
            CALL Attenuation(Atom_pres,Atten,Freq,Temp,Wat_pres)
            IF INT(L/2)=L/2 THEN
                 LINE TYPE 2
            ELSE
                 LINE TYPE 1
            END IF
            PLOT X,Atten
       NEXT X
       LDIR 0
       LORG 2
       CSIZE 3,.6
       MOVE X,Atten
       LINE TYPE 1
       LABEL USING "K";Freq,"Hz"
       Freq=DROUND(Freq*2^(1/3),3)
       J=J+11
     NEXT L
     PRINT "HIT CONTINUE TO CONTINUE"
     PAUSE
     GCLEAR
     OUTPUT KBD;"K";
ELSE
     GCLEAR
     OUTPUT KBD;"K";
END IF
Temp=Temp_con
Freq=Freq_con
SUBEND
!
!
sub Att_temp(Atom_pres,Freq,Temp)
!
!
!      THIS SUBPROGRAM PLOTS THE ATTENUATION OF SOUND VERSUS WATER-
!VAPOR PRESSURE FOR FIVE DIFFERENT TEMPERATURES AT 10 DEGREE
!INTERVALS AROUND THE INPUT TEMPERATURE.
!
!
!      INPUT   ATOMOSPHERIC PRESSURE IN MILLIBARS
!              FREQUENCY OF ACOUSTIC ENERGY IN HERTZ
!              TEMPERATURE IN CELSIUS
!
!      OUTPUT  PLOTS OF ATTENUATION VERSUS WATER-VAPOR PRESSURE
!
!VARIABLES
!
!  Atom_pres   INPUT OF ATMOSPHERIC PRESSURE IN mb.
!  Atten       ATTENUATION OF ACOUSTIC WAVE.  CALCULATED IN
!               SUBPROGRAM ATTENUATION.
!  Att_temp    VARIABLE USED TO DETERMINE IF OPERATOR WANTS
```

```
!               TO PLOT ATTENUATION VERSUS WATER_VAPOR PRESSURE
!               FOR VARIOUS TEMPERATURE AROUND THE INPUT TEMPERATURE.
!               THE PLOT IS DONE IN THE SUBPROGRAM Att_temp.
!  Es          SATURATION VAPOR PRESSURE AT GIVEN TEMPERATURE.
!  Freq        INPUT FREQUENCY OF ECHOSOUNDER.
!  I           MAIN INDEX FOR LOOP TO CHECK RETURNED POWER UNTIL
!  J           FIRST ORDER INDEX FOR ASSORTED LOOPS.
!  L           SECOND ORDER INDEX FOR ASSORTED LOOPS.
!  Temp        INPUT TEMPERATURE IN DEGREES CELSIUS.
!  Temp_con    USED TO INSURE VALUE OF TEMPERATURE PASSED TO SUBPROGRAM
!               Att_temp WAS NOT CHANGED.
!  Wat_pres    ATMOSPHERIC WATER PRESSURE IN MILLIBARS.  INPUT BY
!               OPERATOR.
!  X           THIRD ORDER INDEX USED IN VARIOUS LOOPS.
!  X$          STRING PASSED TO FUNCTION YES TO DETERMINE OPERATOR
!               RESPONSE TO YES OR NO QUESTION.
!  Ymax        LARGEST VALUE OF Y VARIABLE FOR VARIOUS PLOTS.
!
!
Ymax=0
Temp_con=Temp
Temp=Temp+20
FOR J=0 TO 4 STEP .1
     Wat_pres=J
     CALL Attenuation(Atom_pres,Atten,Freq,Temp,Wat_pres)
     IF Atten>Ymax THEN
          Ymax=Atten
     END IF
NEXT J
Ymax=PROUND(Ymax+.005,-2)
GRAPHICS ON
VIEWPORT 15,120,10,70
WINDOW 0,15,0,Ymax
AXES .5,.005,0,0,2,2
CLIP OFF
!LABEL PLOT
CSIZE 4,.6
LDIR 0
MOVE 7.5,Ymax*1.1
LORG 5
LABEL "ATTENUATION VERSUS WATER-VAPOR PRESSURE"
CSIZE 4,.6
!LABEL HORIZONTAL AXES
LDIR 0
LORG 6
FOR J=0 TO 15
     MOVE J,0
     LABEL J
NEXT J
MOVE 7.5,-Ymax*.1
```

```
CSIZE 4,.6
LABEL "WATER-VAPOR PRESSURE   mb"
!LABEL VERTICAL AXES
LORG 8
CSIZE 4,.6
FOR J=0 TO Ymax STEP .01
     MOVE .25,J
     LABEL J
NEXT J
LDIR PI/2
LORG 6
MOVE -2,Ymax*.5
CSIZE 4,.6
LABEL "ATTENUATION   1/m"
!PRINT INPUT CONDITIONS
LDIR 0
LORG 1
MOVE 6,Ymax
CSIZE 4,.6
LABEL USING "K";"ATMOSPHERIC PRESSURE=",Atom_pres," mb"
MOVE 6,Ymax*.95
CSIZE 4,.6
LABEL USING "K";"FREQUENCY=",Freq," HZ"
CLIP ON
J=0
FOR L=1 TO 5
     FOR X=0. TO 6+J STEP .05
          Wat_pres=X
          IF INT(L/2)=L/2 THEN
               LINE TYPE 3
          ELSE
               LINE TYPE 1
          END IF
          CALL Attenuation(Atom_pres,Atten,Freq,Temp,Wat_pres)
          PLOT X,Atten
     NEXT X
     LDIR 0
     LORG 2
     CSIZE 3,.6
     MOVE X,Atten
     LINE TYPE 1
     LABEL USING "K";Temp,"C"
     Temp=Temp-10
     J=J+1.6
NEXT L
PRINT "HIT CONTINUE TO CONTINUE"
PAUSE
GCLEAR
OUTPUT KBD;"K";
FOR J=0 TO 15
```

```
      PRINT " "
  NEXT J
  !
  PRINT "WOULD YOU ARE LIKE TO SEE THE SAME PLOT ONLY"
  PRINT "WITH ATTENUATION VERSUS RELATIVE HUMIDITY"
  LINPUT "IF SO ENTER Y, IF NOT ENTER N",X$
  Att_temp=FNYes(X$)
  IF Att_temp=1 THEN
     OUTPUT KBD;"K";
     Temp=Temp_con
     WINDOW 0,100,0,Ymax
     AXES 10,.005,0,0,2,2
     CLIP OFF
     !LABEL PLOT
     CSIZE 4,.6
     LDIR 0
     MOVE 50,Ymax*1.1
     LORG 5
     LABEL "ATTENUATION VERSUS RELATIVE HUMIDITY"
     !LABEL HORIZONTAL AXIS
     LDIR 0
     LORG 6
     FOR J=0 TO 100 STEP 10
       MOVE J,0
       LABEL J
     NEXT J
     MOVE 50,-Ymax*.1
     CSIZE 4,.6
     LABEL "RELATIVE HUMIDITY"
     !LABEL VERTICAL AXES
     LORG 8
     CSIZE 4,.6
     FOR J=0 TO Ymax STEP .01
       MOVE 2,J
       LABEL J
     NEXT J
     LDIR PI/2
     LORG 6
     MOVE -10,Ymax*.5
     CSIZE 4,.6
     LABEL "ATTENUATION  1/m"
     !PRINT INPUT CONDITIONS
     LDIR 0
     LORG 6
     MOVE 50,Ymax
     CSIZE 4,.6
     LABEL USING "K";"ATMOSPHERIC PRESSURE=",Atom_pres," mb"
     MOVE 50,Ymax*.95
     CSIZE 4,.6
     LABEL USING "K";"FREQUENCY=",Freq," Hz"
```

```
   CLIP ON
   J=0
   Temp=Temp-20
   FOR L=1 TO 5
     T=Temp+273
     Es=10^(9.4-2353/T)
     FOR X=0 TO 90-J STEP .5
          Wat_pres=Es*Atom_pres*X/((Atom_pres-Es*(1+X/100))*100)
          IF INT(L/2)=L/2 THEN
               LINE TYPE 3
          ELSE
               LINE TYPE 1
          END IF
          CALL Attenuation(Atom_pres,Atten,Freq,Temp,Wat_pres)
          PLOT X,Atten
     NEXT X
     LDIR 0
     LORG 2
     CSIZE 3,.6
     MOVE X,Atten
     LINE TYPE 1
     LABEL USING "K";Temp," C"
     Temp=Temp+10
     J=J+15
   NEXT L
   PRINT "HIT CONTINUE TO CONTINUE"
   PAUSE
   GCLEAR
   OUTPUT KBD;"K";
ELSE
   OUTPUT KBD;"K";
END IF
Temp=Temp_con
SUBEND
!
!
!
sub Log_log(Xmin,Xmax,Ymin,Ymax,Xvar(*),J,Range(*),L,Title$,Xlabel$,Ylabel

!
!     THIS SUBROUTINE MAKES A LOG-LOG PLOT OF DATA PASSED FROM THE
!MAIN PROGRAM.
!
!     INPUT   MINIMUM VALUES OF X AND Y FOR PLOT
!             MAXIMUM VALUES OF X AND Y FOR PLOT
!             X AND Y VALUES TO BE PLOTTED
!             TITLE OF PLOT
!             LABELS FOR X AND Y AXIS
!     OUTPUT  LOG-LOG PLOT
!
```

```
!VARIABLES
!   Dx          STEP SIZE FOR X AXIS FOR VARIOUS PLOTS.
!   Dy          STEP SIZE FOR Y AXIS FOR VARIOUS PLOTS.
!   J           FIRST ORDER INDEX FOR ASSORTED LOOPS.
!   L           SECOND ORDER INDEX FOR ASSORTED LOOPS.
!   Title$      STRING PASSED TO SUBPROGRAM PT FOR TITLE OF PLOT.
!   Xlabel$     LABEL ON X AXIS PASSED TO SUBPROGRAM Pt FOR PLOTTING.
!   Xmax        VALUE OF LARGEST VALUE OF X FOR VARIOUS PLOTS.
!   Xmin        VALUE OF SMALLEST VALUE OF X FOR VARIOUS PLOTS.
!   Xrange      VALUE OF RANGE OF X VALUES FOR VARIOUS PLOTS.
!   Xvar(*)     VALUE OF ARRAY OF X VALUES TO BE PLOTTED IN SUBPROGRAM Pt.
!   Ylabel$     LABEL ON Y AXIS PASSED TO SUBPROGRAM Pt FOR PLOTTING.
!   Ymax        LARGEST VALUE OF Y VARIABLE FOR VARIOUS PLOTS.
!   Ymin        SMALLEST VALUE OF Y VARIABLE FOR VARIOUS PLOTS.
!   Yrange      RANGE OF Y VARIABLES FOR VARIOUS PLOTS.
!
Dx=1
Dy=1
Xrange=ABS(Xmax-Xmin)
Yrange=ABS(Ymax-Ymin)
WINDOW Xmin,Xmax,Ymin,Ymax
AXES Dx,Dy,Xmin,Ymin,1,1
CLIP OFF
!
!LABEL PLOT
CSIZE 4,.6
LDIR 0
LORG 5
MOVE Xmin+.5*Xrange,1.1*Yrange
Title$=TRIM$(Title$)
LABEL Title$
!LABEL HORIZONTAL AXES
LDIR 0
LORG 5
FOR J=Xmin TO Xmax STEP Dx
     CSIZE 4,.6
     MOVE J-.013*Xrange,-.067*Yrange
     LABEL "10"
     MOVE J+.013*Xrange,-.033*Yrange
     CSIZE 2
     LABEL J
NEXT J
MOVE Xmin+.5*Xrange,-.12*Yrange
LORG 5
CSIZE 4,.6
Xlabel$=TRIM$(Xlabel$)
LABEL Xlabel$
!LABEL VERTICAL AXES
LORG 8
FOR J=0 TO Ymax STEP Dy
```

```
     CSIZE 4,.6
     MOVE Xmin-.025*Xrange,J
     LABEL "10"
     CSIZE 2
     MOVE Xmin-.0025*Xrange,J+.03*Yrange
     LABEL J
NEXT J
LDIR PI/2
LORG 6
MOVE Xmin-.1*Xrange,.5*Yrange
CSIZE 4,.6
Ylabel$=TRIM$(Ylabel$)
LABEL Ylabel$
CLIP ON
FOR J=1 TO L
     PLOT LGT(Xvar(J)),LGT(Range(J))
NEXT J
SUBEND
```

APPENDIX B

COMPUTER PROGRAM 2

```
!FULLER, ROBERT       PROG_2      FREQUENCY
!
!9 SEP 85
!
!
!*******PURPOSE*******
!
!     THIS PROGRAM WILL TAKE PARAMETERS OF AN ECHOSOUNDER AND
!ESTIMATE THE RANGE AS A FUNCTION OF FREQUENCY.  THE FOLLOWING INPUTS
!ARE REQUIRED:
!    ATMOSPHERIC DATA
!    1)ATOMOSPHERIC PRESSURE in millibars
!    2)SELECT ONE OF FOUR ATMOSPHERIC PROFILES FOR THE TEMPERATURE
!      STRUCTURE PROFILE.
!       a)FOR ONE PROFILE THE HEIGHT OF THE INVERSION LAYER IS ALSO INPUT
!    3)TEMPERATURE IN DEGREES CELSIUS
!    4)WATER VAPOR PRESSURE IN millibars
!
!    ECHOSOUNDER DATA
!    5)ANTENNA DIAMETER IN METERS
!    6)POWER TRANSMITTED BY ECHOSOUNDER IN WATTS
!    7)PULSE LENGTH OF THE TRANSMITTED ACOUSTIC ENERGY
!
!THE PROGRAM OUTPUTS THE FOLLOWING GRAPHS TO AN EXTERNAL PLOTTER:
!    1)RANGE(m.) VERSUS FREQUENCY OF ECHOSOUNDER
!    2)RANGE(m.) VERSUS EXCESS ATTENUATION FOR VARIOUS FREQUENCUIES
!
!
!*****VARIABLES*****
!
!
!  Again      TEST VALUE IN WHILE LOOP TO DETERMINE IF OPERATOR
!              WISHES TO MAKE ANOUTHER RUN.
!  Ano_change TEST VALUE IN WHILE LOOP TO DETERMINE IF OPERATOR
!              WISHES TO CHANGE THE VALUE OF INPUT DATA BEFORE MAKING
!              ANOUTHER RUN.
!  Ant_area   ECHOSOUNDER ANTENNA AREA CALCULATED FROM INPUT OF
!              ANTENNA DIAMETER.
!  Ant_diam   INPUT OF ECHOSOUNDER ANTENNA DIAMETER IN METERS.
!  Atom_pres  INPUT OF ATMOSPHERIC PRESSURE IN mb.
!  Atten      ATTENUATION OF ACOUSTIC WAVE.  CALCULATED IN
!              SUBPROGRAM ATTENUATION.
!  Bn         BANDWIDTH OF RECEIVER NEEDED TO RECEIVE SIGNALS
!              DOPPLER SHIFFED BY THREE METER PER SECOND
!              VERTICAL VELOCITIES.
!  C          VELOCITY OF SOUND CALCULATION AT ZERO CELSIUS.
!  C1         VARIABLE USED TO SCALE INVERSION HEIGHT IN
!              TEMPERATURE STRUCTURE PROFILE THREE.
!  C3         VARIABLE USED IN CALCULATING THE FOURTH Cte2 PROFILE.
!  Cne2(*)    ARRAY OF VALUES OF THE ACOUSTIC REFRACTIVE INDEX
```

```
!               PARAMETER.  CALCULATED BASED ON SELECTION OF
!               PROFILE FOR TEMPERATURE STRUCTURE PARAMETER
!               AND ASSUMED PROFILE FOR THE VELOCITY STRUCTURE
!               PARAMETER.
! Cte2         VALUE OF THE TEMPERATURE STRUCTURE PARAMETER.
!               THE OPERATOR SELECTS A PROFILE FROM SEVERAL PROVIDED.
! Cve2         VALUE OF THE VELOCITY STRUCTURE  PARAMETER.
!               VALUES BASED ON CALCULATION USING ASSUMED DISSAPATION
!               RATE.
! Dx           STEP SIZE FOR X AXIS FOR VARIOUS PLOTS.
! Dy           STEP SIZE FOR Y AXIS FOR VARIOUS PLOTS.
! Epsilon      DISSAPATION RATE USED IN CALCULATION OF Cve2.
! Et           TRANSMISSION EFFICIENCY OF ECHOSOUNDER.
! Er           EFFICIENCY OF ECHOSOUNDER WHEN RECEIVING ACOUSTIC
!               BACKSCATTER.
! Exc_att(*,*) EXCESS "ATTENUATION" AT GIVEN RANGE.
! F            VARIABLE USED IN SUBPROGRAM ATTENUATION.  IS THE
!               RATIO OF FREQUENCY TO FREQUENCY AT MAXIMUM ATTENUATION.
! Fmax         FREQUENCY OF MAXIMUM ATTENUATION. USED IN SUBPROGRAM
!               ATTENUATION.
! Freq         INPUT FREQUENCY OF ECHOSOUNDER.
! G            ANTENNA EFFECTIVE APERATURE FACTOR.
! H            VARIABLE USED IN INTEGRATION FOR EXCESS ATTENUATION.
! I            MAIN INDEX FOR LOOP TO CHECK RETURNED POWER UNTIL
!               POWER WAS LESS THAN MINIMUM DETECTABLE SIGNAL.
! IND          INDEX USED FOR LOOP FOR DIFFERENT FREQUENCIES
! Interval     MAXIMUM EFFECTIVE-SCATTERING VOLUME THICKNESS.
! Inver        HEIGHT OF INVERSION LAYER.
! J            FIRST ORDER INDEX FOR ASSORTED LOOPS.
! K            WAVENUMBER
! L            SECOND ORDER INDEX FOR ASSORTED LOOPS.
! Mess_up      TEST VALUE TO CHECK RESPONSES WHEN OPERATOR IS INPUTTING
!               RESPONSES.
! N            TEST VALUE IN CALCULATION OF COHERENCE LENTH IN CALCULATION
!               OF EXCESS ATTENUATION.
! New_va       TEST VALUE IN CHECKING IF OPERATOR WISHES TO CHANGE
!               A VARIABLE BEFORE A NEW RUN.
! Noise        ASSUMED MINIMUM DETECTABLE SIGNAL.
! Pow_back(*) POWER BACKSCATTERED FROM GIVEN RANGE.
! Pow_ret(*) POWER BACKSCATTERED TO ECHOSOUNDER FROM GIVEN RANGE.
! Pow_trans    INPUT OF POWER SUPPLIED TO TRANSDUCER OF ECHOSOUNDER.
! Profile      OPERATOR INPUT OF Cte2 PROFILE FROM AVAILABLE PROFILES.
! Pstar        VARIABLE USED IN SUBPROGRAM ATTENUATION FOR INTERMEDIATE
!               CALCULATION.
! Pulse        TRANSMITTED PULSE LENGTH IN MILLISECONDS.  INPUT BY
!               OPERATOR.
! R            RANGE FOR INPUT TO INTEGRAL OF EXCESS ATTENUATION.
! R1           VARIABLE USED IN SCALING INVERSION HEIGHT FOR PROFILE THREE.
! Range(*)     ARRAY OF RANGE VALUES.
! Remainder    REMAINDER OF MODULO FUNCTION USED TO DECREES THE
```

```
!              NUMBER OF PASSES THROUGH THE INTEGRATION FOR EXCESS
!              ATTENUATION.
!  Rge         VALUE OF RANGE IN INTEGRAL FOR EXCESS ATTENUATION.
!  Rho         CORRELATION LENGTH USED IN CALCULATION OF EXCESS
!              ATTENUATION.
!  Sigma       FRACTION OF ENERGY BACKSCATTERED FROM GIVEN RANGE.
!  Speed_sound SPEED OF SOUND IN AIR AT INPUT TEMPERATURE.
!  Sumpow_back SUM OF BACKSCATTERED ENERGY
!  T           INPUT TEMPERATURE IN DEGREES KELVIN.
!  Temp        INPUT TEMPERATURE IN DEGREES CELSIUS.
!  Temp$       VARIABLE STRING USED IN FUNCTION YES.
!
!  Title$      STRING PASSED TO SUBPROGRAM Semi_log FOR TITLE OF PLOT.
!  Tstar       INTERMEDIATE VALUE USED IN CALCULATION OF ATTENUATION
!              IN SUBPROGRAM ATTENUATION.
!  Var         USED TO SELECT THE VARIABLE THE OPERATOR WISHED TO
!              CHANGE BEFORE MAKING ANOTHER RUN.
!  Wat_pres    ATMOSPHERIC WATER PRESSURE IN MILLIBARS.  INPUT BY
!              OPERATOR.
!  X           THIRD ORDER INDEX USED IN VARIOUS LOOPS.
!  X$          STRING PASSED TO FUNCTION YES TO DETERMINE OPERATOR
!              RESPONSE TO YES OR NO QUESTION.
!  Xlabel$     LABEL ON X AXIS PASSED TO SUBPROGRAM Semi_log FOR PLOTTING.
!  Xmax        VALUE OF LARGEST VALUE OF X FOR VARIOUS PLOTS.
!  Xmin        VALUE OF SMALLEST VALUE OF X FOR VARIOUS PLOTS.
!  Xrange      VALUE OF RANGE OF X VALUES FOR VARIOUS PLOTS.
!  Xvar(*)     VALUE OF ARRAY OF X VALUES TO BE PLOTTED IN SUBPROGRAM Semi_

!  Ylabel$     LABEL ON Y AXIS PASSED TO SUBPROGRAM Semi_log FOR PLOTTING.
!  Ymax        LARGEST VALUE OF Y VARIABLE FOR VARIOUS PLOTS.
!  Ymin        SMALLEST VALUE OF Y VARIABLE FOR VARIOUS PLOTS.
!  Yrange      RANGE OF Y VARIABLES FOR VARIOUS PLOTS.
!  Ze          INTERMEDIATE VALUE IN CALCULATION OF EXCESS ATTENUATION.
!
!
!DECLARE VARIABLES
INTEGER I
DIM Pow_back(1500),Pow_ret(1500),Range(1500)
DIM Cne2(1500),Exc_att(1500,30),Xvar(1500),Ran(30)
DIM Title$[50],Xlabel$[50],Ylabel$[16]
!
PLOTTER IS 705,"HPGL"
LINE TYPE 1
!
!INPUT ATMOSPHERIC DATA
INPUT "ENTER TEMPERATURE IN DEGREES CELCIUS",Temp
INPUT "ENTER ATMOSPHERIC PRESSURE IN MILLIBARS",Atom_pres
INPUT "ENTER WATER VAPOR PRESSURE IN MILLIBARS",Wat_pres
!
!
```

```
!INPUT ECHOSOUNDER DATA
INPUT "ENTER ANTENNA DIAM IN METERS",Ant_diam
INPUT "ENTER ECHOSOUNDER PULSE LENGTH IN MILLISECONDS=",Pulse
INPUT "ENTER POWER TO TRANSMITTER IN WATTS",Pow_trans
Et=.25          !TRANSMIT EFFICIENCY
Er=.25          !RECEIVER EFFICIENCY
G=.40          !ANTENNA EFFECTIVE APERATURE FACTOR
!
!
!SELECT THE PROFILE FOR THE TEMPERATURE STRUCTURE
PRINT "YOU HAVE A CHOICE OF TEMPERATURE STRUCTURE PROFILES"
PRINT "PROFILE TO BE USED."
PRINT "YOUR SELECTIONS ARE"
PRINT "     1      A TEMPERARURE STRUCTURE PROFILE BASED ON DATA AS "
PRINT "            PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398 WHICH "
PRINT "             GIVES A HEIGHT TO THE -1.16 PROFILE"
PRINT " "
PRINT "     2      THE TEMPERATURE STRUCTURE PROFILE ABOVE BUT"
PRINT "            WITH A FACTOR OF TWO TO APPROXIMATE LOOKING"
PRINT "            UP A THERMAL PLOOM"
PRINT " "
PRINT "     3      A TEMPERATURE STRUCTURE PROFILE BASED ON DATA AS"
PRINT "            PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398 FOR"
PRINT "            NIGHT CONDITIONS.  THE DEPENDENCE WITH HEIGHT "
PRINT "            IS EXP(-.001*HEIGHT ABOVE 65 METERS AND HEIGHT"
PRINT "            TO THE -1.46 BELOW 65 METERS"
PRINT " "
PRINT "     4      A TEMPERATURE STRUCTURE PROFILE BASED ON A"
PRINT "             HEIGHT TO THE -4/3 "
!
PRINT " "
PRINT " "
Mess_up=1
WHILE Mess_up=1
     INPUT "ENTER THE DESIRED PROFILE (1 OR 2 OR 3 OR 4)",Profile
     IF Profile=4 THEN
          INPUT "ENTER THE HEIGHT OF THE INVERSION IN METERS",Inver
     END IF
     IF Profile=1 THEN
         Mess_up=0
     ELSE
         IF Profile=2 THEN
              Mess_up=0
         ELSE
              IF Profile=3 THEN
                   Mess_up=0
              ELSE
                   IF Profile=4 THEN
                        Mess_up=0
                   ELSE
```

```
                        PRINT Profile," WAS NOT ONE OF THE OPTIONS!!!!"
                        Mess_up=1
                   END IF
              END IF
         END IF
      END IF
END WHILE
OUTPUT KBD;"K";
!
!
Again=1
WHILE Again=1
  FOR J=1 TO I
     Pow_back(J)=0
     Pow_ret(J)=0
     Range(J)=0
     Cne2(J)=0
     FOR L=1 TO Ind
          Exc_att(J,L)=0
     NEXT L
  NEXT J
  !
  !CONVERT TEMPERATURE TO KELVIN
  T=Temp+273
  !
  !CALCULATE SPEED OF SOUND BASED ON INPUT TEMPERATURE(CELCIUS)
  Speed_sound=20.05*(T)^.5
  !CALCULATE THE SPEED OF SOUND AT 0 DEGREES CELCIUS
  C=20.05*273^.5
  !
  I=1     !INDEX FOR LOOP
  Ind=1
  Pow_back(0)=0    !INITIALIZE VARIABLE FOR POWER BACKSCATERRED
  Ant_area=PI*(Ant_diam/2)^2   !ANTENNA AREA
  Interval=(Speed_sound*Pulse*1.E-3)/2
  !
  !INITIALIZE PLOTTING PARAMETERS SO CAN COMPARE DURING RUN TO SCALE
  !PLOTS
  Ymin=1000
  Ymax=0
  !CALCULATE RETURNED SIGNAL POWER UNTIL IT IS LESS THAN BACKGROUND
  !FOR EACH FREQUENCY.
  Range(0)=0
  FOR Freq=100 TO 3000 STEP 100
   Bn=2*Freq*(1-1/(6/Speed_sound+1))!BANDWIDTH FOR 3M/S VERTICAL VELOCITY
   Noise=1.38E-23*Bn*(T)+2.E-14!MINIMUM DETECTABLE SIGNAL AS
   !      JOHNSON NOISE(NEGLIGABLE)+ ESTIMATED BACKGROUND
   !CALCULATE THE ATTENUATION COEFFICIENT BASED ON ATMOSPHERIC DATA
   CALL Attenuation(Atom_pres,Atten,Freq,Temp,Wat_pres)
   K=2*PI*Freq/Speed_sound    !WAVENUMBER
```

```
I=1
Sumpow_back=0
REPEAT
  Range(I)=Range(I-1)+2
  SELECT Profile
        CASE 1
        !THIS TEMPERATURE STRUCTURE PROFILE IS BASED UPON DATA
        !AS PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398.
        !WAS FOR MIDDAY AND CLEAR WEATHER ABOVE THE
        !TULAROSA BASIN, NEW MEXICO.
        !AN ADDITONAL FACTOR OF 1.8 WAS INCLUDED AS PER DIFFERENT
        !AVERAGING TIME.
            Cte2=2.12*Range(I)^(-1.16)
        CASE 2
        !THIS TEMPERATURE STRUCTURE PROFILE IS BASED UPON DATA
        !AS PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398.
        !WAS FOR MIDDAY AND CLEAR WEATHER ABOVE THE
        !TULAROSA BASIN, NEW MEXICO.
        !AN ADDITONAL FACTOR OF 1.8 WAS INCLUDED AS PER DIFFERENT
        !AVERAGING TIME AND AN ADDITIONAL FACTOR OF TWO WAS
        !INCLUDED TO APPROXIMATE LOOKING UP A THERMAL PLOOM
            Cte2=2*2.12*Range(I)^(-1.16)
        CASE 3
        !THIS TEMPERATURE STRUCTURE PROFILE BASED ON DATA AS"
        !PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398 FOR"
        !NIGHT CONDITIONS.  THE DEPENDENCE WITH HEIGHT "
        !IS EXP(-.001*HEIGHT ABOVE 65 METERS AND HEIGHT"
        !TO THE -1.46 BELOW 65 METERS"
            IF Range(I)<65 THEN
                 Cte2=75.5*Range(I)^(-1.46)
            ELSE
                 Cte2=3.66E-2*EXP(-.001*Range(I))
            END IF
        CASE 4
        !CALCULATE THE TEMPERATURE STRUCTURE FACTOR BASED ON ASSUMPTION
        !    THAT IT'S PROPORTIONAL TO HEIGHT TO THE -4/3 POWER
        !    THAT THE SURFACE VERTICAL HEAT FLUX IS .095 C.m./sec
        !THE DEPENDENCE WITH HEIGHT ABOVE THE INVERSION I PULLED FROM
        !MY LEFT EAR
        !EQUATION FROM NEFF, 1975
        SELECT Range(I)/Inver
             CASE <.9
                 C3=((.024)*(T)^(.667))
                 Cte2=C3*(Range(I))^(-1.33)
             CASE .9 TO 1
                 Cte2=Cte2
                 C1=Cte2
                 R1=Range(I)
             CASE 1 TO 1.3
                 Cte2=10^((LGT(C3*Range(I))-LGT(C3*R1))+LGT(C1))
```

```
                R2=Range(I)
                C2=Cte2
            CASE ELSE
                Cte2=C3*(Range(I)^(-1.33)-R2^(-1.33))+C2
        END SELECT
    END SELECT
    !CALCULATE VELOCITY STRUCTURE FACTOR. FORMULA FROM GAYNOR 77
    Epsilon=(.2866/Range(I))*(1+.07*(Range(I))^(.6))^(1.5)
    Cve2=2*Epsilon^(.667)
    !CALCULATE ACOUSTIC REFRACTIVE INDEX STRUCTURE FACTOR.
    !FORMULA FROM TETARSKI
    Cne2(I)=(Cte2/(2.98E+5))+(Cve2/(C*C))
    !CALCULATE THE FRACTION OF POWER BACKSCATTERED FROM INTERVAL.
    !EQUATION FROM NEFF, 1975
    Sigma=(.0039*(K^(1/3))*Cte2)/(T)^2
    !
    !CALCULATE THE EXCESS ATTENUATION.  EQUATION FROM CLIFFORD, 1980
    !THE EXCESS ATTENUATION IS Exc_att(I,L,X)
    IF I<50 THEN
        Remainder=0
    ELSE
        IF I<150 THEN
            Remainder=Range(I) MODULO 10
        ELSE
            Remainder=Range(I) MODULO 20
        END IF
    END IF
    IF Remainder=0 THEN
        Rho=0
        L=0
        H=0
        Rge=Range(I)     !CONSTANT IN INTEGRAL
        R=0
        FOR J=0 TO 2*I
                    F=Cne2(INT(J/2+1))
                    F=F*(1-R/(Rge)^(1.67)+(R/(Rge))^(1.67))
                    IF J>0 THEN
                        IF J<2*I THEN
                            IF INT(J/2)=J/2 THEN
                                L=L+F
                                F=0
                            ELSE
                                H=H+F
                                F=0
                            END IF
                        END IF
                    END IF
                    Rho=Rho+F
                    R=R+1
        NEXT J
```

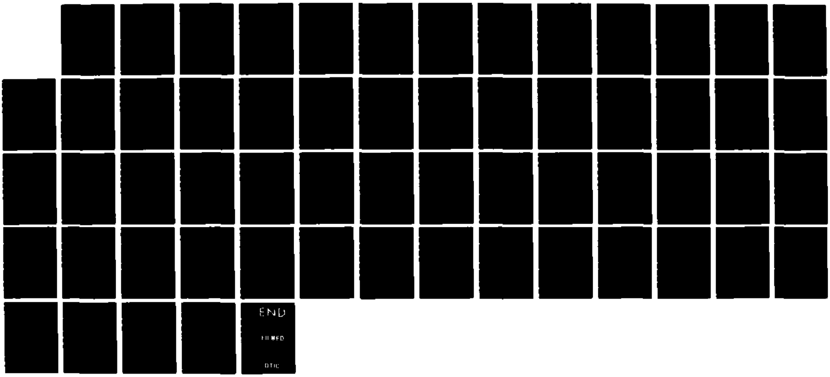
```
        Rho=Rho+4*L+2*H
        Rho=(((Rho*.33)*K*K*1.46)^(-.6))
        N=(Ant_diam/Rho)^2
        IF N<=1 THEN
             Ze=1/(1+N)
        ELSE
             Ze=1.5/(1+N)
             !STEP OF 1.5==>SEE CLIFFORD 1980
        END IF
        Exc_att(I,Ind)=Ze*Ze
   ELSE
        Exc_att(I,Ind)=Exc_att(I-1,Ind)
   END IF
   !
   !CALCULATE THE POWER BACKSCATTERED
   Pow_back(I)=(Pow_trans*Et-Sumpow_back)*EXP(-Atten*Range(I))
   Pow_back(I)=Pow_back(I)*Interval*Exc_att(I,Ind)*Sigma
   Sumpow_back=Sumpow_back+Pow_back(I)
   !CALCULATE THE POWER BACKSCATTERED TO THE ANTENNA
   Pow_ret(I)=Pow_back(I)*EXP(-Atten*Range(I))*Ant_area*G*Er/Range(I)^2
   PRINT "RANGE=",Range(I)
   PRINT "POWER RETURNED=",Pow_ret(I)
   I=I+1
 UNTIL Pow_ret(I-1)>0 AND Pow_ret(I-1)<=Noise
 Ran(Ind)=Range(I-2)
 IF Range(I-2)>Ymax THEN
      Ymax=Range(I-2)
 END IF
 IF Range(I-2)<Ymin THEN
      Ymin=Range(I-2)
 END IF
 Ind=Ind+1
 Again=1
 FOR J=1 TO I
     Pow_back(J)=0
     Pow_ret(J)=0
     Range(J)=0
     Cne2(J)=0
 NEXT J
 PRINT "FREQUENCY=",Freq
NEXT Freq
!
!
OUTPUT KBD;"K";
PRINT "INPUT CONDITIONS"
!
PRINT " "
PRINT USING "K";"TEMPERATURE=             ",Temp,"CELCIUS"
PRINT USING "K";"ATMOSPHERIC PRESSURE=    ",Atom_pres,"mb"
PRINT USING "K";"WATER VAPOR PRESSURE=    ",Wat_pres,"mb"
```

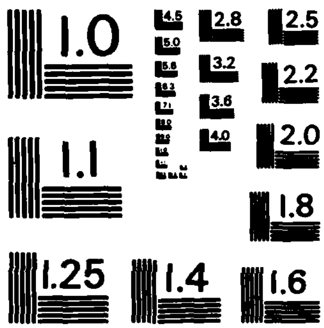
```
PRINT USING "K";"PULSE LENGTH=           ",Pulse,"ms"
PRINT USING "K";"ANTENNA DIAMETER=       ",Ant_diam," m."
PRINT USING "K";"POWER TRANSMITTED=      ",Pow_trans," WATTS"
PRINT "TEMPERATURE STRUCTURE PROFILE USED ",Profile
IF Profile=4 THEN
   PRINT "INVERSION HEIGHT ",Inver
END IF
SELECT Profile
   CASE 1
       PRINT "     1      A TEMPERARURE STRUCTURE PROFILE BASED ON DATA"
       PRINT "            AS PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398 "
       PRINT "            WHICH GIVES A HEIGHT TO THE -1.16 PROFILE"
   CASE 2
       PRINT "     2      A TEMPERARURE STRUCTURE PROFILE BASED ON DATA"
       PRINT "            AS PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398 "
       PRINT "            WHICH GIVES A HEIGHT TO THE -1.16 PROFILE"
       PRINT "            BUT WITH A FACTOR OF TWO TO APPROXIMATE"
       PRINT "            LOOKING UP A THERMAL PLOOM"
   CASE 3
       PRINT "     3      A TEMPERATURE STRUCTURE PROFILE BASED ON DATA"
       PRINT "            AS PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398"
       PRINT "            FOR NIGHT CONDITIONS.  THE DEPENDENCE WITH"
       PRINT "            HEIGHT IS EXP(-.001*HEIGHT ABOVE 65 METERS"
       PRINT "            AND HEIGHT TO THE -1.46 BELOW 65 METERS"
   CASE 4
       PRINT "     4      A TEMPERATURE STRUCTURE PROFILE BASED ON A"
       PRINT "             HEIGHT TO THE -4/3 "
END SELECT
!
PRINT USING "K";"THE MINIMUM DETECTABLE SIGNAL WAS SET AT",Noise,"WATTS"
!
PRINT " "
!
!
PRINT "HIT CONTINUE TO CONTINUE"
PAUSE
OUTPUT KBD;"K";
!
GRAPHICS ON
VIEWPORT 15,120,10,70
!
!
!PLOT RANGE VERSUS FREQUENCY
Xmin=0
Xmax=3000
Ymin=PROUND(Ymin-50,2)
Ymax=PROUND(Ymax+50,2)
Dx=500
Dy=100
Xrange=Xmax-Xmin
```

```
Yrange=Ymax-Ymin
WINDOW Xmin,Xmax,Ymin,Ymax
AXES Dx,Dy,Xmin,Ymin,2,1
CLIP OFF
!
!LABEL PLOT
CSIZE 4,.6
LDIR 0
LORG 5
MOVE .5*Xrange,Ymax*1.05
LABEL "RANGE VERSUS FREQUENCY"
!LABEL HORIZONTAL AXES
LDIR 0
LORG 5
FOR J=0 TO Xmax STEP Dx
   CSIZE 4,.6
   MOVE J,Ymin-.05*Yrange
   LABEL J
NEXT J
MOVE .5*Xrange,Ymin-.1*Yrange
CSIZE 4,.6
LABEL "FREQUENCY"
!LABEL VERTICAL AXES
LORG 8
FOR J=Ymin TO Ymax STEP Dy
   CSIZE 4,.6
   MOVE Xmin-.0025*Xrange,J
   LABEL USING "K";J
NEXT J
LDIR PI/2
LORG 6
MOVE Xmin-.15*Xrange,.5*Yrange+Ymin
CSIZE 4,.6
LABEL "RANGE (METERS)"
CLIP ON
Ind=1
FOR Freq=100 TO 3000 STEP 100
   PLOT Freq,Ran(Ind)
   Ind=Ind+1
NEXT Freq
!
PRINT "HIT CONTINUE TO CONTINUE"
PAUSE
GCLEAR
OUTPUT KBD;"K";
!
!
!PLOT RANGE VERSUS EXCESS ATTENUATION
!
Xmin=0
```

AD-A162 138 PARAMETRIC ANALYSIS OF ECHOSOUNDER PERFORMANCE(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA R J FULLER SEP 85 2/2

UNCLASSIFIED F/G 20/1 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

```
Ymax=4
Xmax=1
Ymin=0
Range(0)=0
Title$="RANGE vs EXCESS ATTENUATION"
Xlabel$="EXCESS ATTENUATION"
Ylabel$="RANGE (METERS)"
Dx=.1
Dy=1
Xrange=ABS(Xmax-Xmin)
Yrange=ABS(Ymax-Ymin)
WINDOW Xmin,Xmax,Ymin,Ymax
AXES Dx,Dy,Xmin,Ymin,1,1
CLIP OFF
!
!LABEL PLOT
CSIZE 4,.6
LDIR 0
LORG 5
MOVE Xmin+.5*Xrange,1.1*Yrange
Title$=TRIM$(Title$)
LABEL Title$
!LABEL HORIZONTAL AXES
LDIR 0
LORG 5
FOR J=Xmin TO Xmax STEP Dx
   MOVE J,-.033*Yrange
   CSIZE 4,.6
   LABEL J
NEXT J
MOVE Xmin+.5*Xrange,-.12*Yrange
LORG 5
CSIZE 4,.6
Xlabel$=TRIM$(Xlabel$)
LABEL Xlabel$
!LABEL VERTICAL AXES
LORG 8
FOR J=0 TO Ymax STEP Dy
   CSIZE 4,.6
   MOVE Xmin-.025*Xrange,J
   LABEL "10"
   CSIZE 2
   MOVE Xmin-.0025*Xrange,J+.03*Yrange
   LABEL J
NEXT J
LDIR PI/2
LORG 6
MOVE Xmin-.1*Xrange,.5*Yrange
CSIZE 4,.6
Ylabel$=TRIM$(Ylabel$)
```

```
LABEL Ylabel$
FOR L=5 TO Ind-1 STEP 5
     X=1
     WHILE Exc_att(X,L)>0
          Xvar(X)=Exc_att(X,L)
          Range(X)=Range(X-1)+2
          X=X+1
     END WHILE
     IF INT(L/2)=L/2 THEN
          LINE TYPE 1
     ELSE
          LINE TYPE 3
     END IF
     Freq=L*100
     CALL Semi_log(Freq,Xvar(*),X-1,Range(*),X-1)
NEXT L
PRINT "HIT CONTINUE TO CONTINUE"
PAUSE
!
GCLEAR
OUTPUT KBD;"K";
LINPUT "WOULD YOU LIKE TO MAKE ANOTHER RUN (ENTER Y OR N)?",X$
Again=FNYes(X$)
Mess_up=1
WHILE Mess_up=1
 SELECT Again
   CASE 1
       LINPUT "WOULD YOU LIKE TO CHANGE A VARIABLE (ENTER Y OR N)?",X$
        New_va=FNYes(X$)
        Ano_change=1
        WHILE Ano_change=1
          SELECT New_va
             CASE 1
              PRINT "       VARIABLE             CURRENT VALUE"
              PRINT USING "K";"1  TEMPERATURE          ",Temp,"CELSIUS"
              PRINT USING "K";"2  ATOMOSPHERIC PRESSURE ",Atom_pres,"mb"
              PRINT USING "K";"3  WATER VAPOR PRESSURE ",Wat_pres,"mb"
              PRINT " "
              PRINT USING "K";"4  ANTENNA DIAMETER      ",Ant_diam," m."
              PRINT USING "K";"5  PULSE LENGTH          ",Pulse," ms"
              PRINT USING "K";"6  POWER TRANSMITTED ",Pow_trans," WATTS"
              PRINT USING "K";"7  ATMOSPHERIC PROFILE  ",Profile
              PRINT " "
              PRINT "ENTER THE NUMBER OF THE VARIABLE YOU WISH TO"
              PRINT "CHANGE"
              INPUT Var
              SELECT Var
                       CASE 1
                          INPUT "TEMPERATURE=",Temp
                       CASE 2
```

```
                  INPUT "ATMOSPHERIC PRESSURE IN mb=",Atom_pres
                CASE 3
                  INPUT "WATER VAPOR PRESSURE IN mb=",Wat_pres
                CASE 4
                  INPUT "ANTENNA DIAMETER IN m.=",Ant_diam
                CASE 5
                  INPUT "PULSE LENGTH IN ms=",Pulse
                CASE 6
                  INPUT "POWER TRANSMITTED IN WATTS=",Pow_trans
                CASE 7
                 PRINT " 1  ==> Ct^2 PROFILE OF Z^(-1.16)"
                 PRINT "        FROM WALTERS/KUNDEL 1981"
                 PRINT " 2  ==> SAME AS ONE BUT WITH FACTOR"
                 PRINT "        OF TWO TO APPROXIMATE LOOKING"
                 PRINT "        UP A THERMAL PLOOM"
                 PRINT " 3  ==> Ct^2 PROFILE OF EXP(-.001*Z)"
                 PRINT "        FROM WALTERS/KUNDEL 1981."
                 PRINT " 4  ==> CT^2 PROFILE OF Z^(-4/3)"
                 INPUT "ENTER NUMBER OF DESIRED PROFILE",Profile
                 IF Profile=4 THEN
                  INPUT "HEIGHT OF INVERSION IN METERS=",Inver
                 END IF
                CASE ELSE
                 PRINT Var,"IS NOT ONE OF THE OPTIONS"
              END SELECT
              LINPUT "MADE ANOTHER CHANGE(ENTER Y OR N)?",X$
              New_va=FNYes(X$)
              Mess_up=2
          CASE 2
              Mess_up=2
              Ano_change=2
          CASE ELSE
              PRINT "YOUR CHOICES WHERE Y OR N !!!!!"
              Ano_change=1
              LINPUT "CHANGE A VARIABLE (ENTER Y OR N)?",X$
              New_va=FNYes(X$)
       END SELECT
      END WHILE
   CASE 2
      Mess_up=2
   CASE ELSE
      PRINT "YOUR CHOICES WHERE Y OR N  !!!!!!"
      Mess_up=1
      LINPUT "MAKE ANOTHER RUN (ENTER Y OR N)?",X$
      Again=FNYes(X$)
  END SELECT
 END WHILE
END WHILE
PRINT "THAT'S ALL, FOLKS"
end
```

```
!
!
!CALCULTE THE ATTENUATION
sub Attenuation(Atom_pres,Atten,Freq,Temp,Wat_pres)
!THIS SUBPROGRAM CALCULATES THE ATTENUATION OF SOUND
!IN AIR BASED UPON EQUATIONS IN NEFF 1975
!
!   INPUT   ATMOSPHERIC PRESSURE IN MILLIBARS
!           FREQUENCY OF SOUND WAVE IN HERTZ
!           TEMPERATURE IN DEGREES CELCIUS
!           WATER-VAPOR PRESSURE IN MILLIBARS
!
!   OUTPUT  ATTENUATION IN 1/METERS
!
!VARIABLES
!  Atom_pres  INPUT OF ATMOSPHERIC PRESSURE IN mb.
!  Atten      ATTENUATION OF ACOUSTIC WAVE.  CALCULATED IN
!              SUBPROGRAM ATTENUATION.
!  Att_max    VARIABLE IN SUBPROGRAM ATTENUATION.  IT IS THE
!              ATTENUATION AT THE FREQUENCY OF THE MAXIMUM
!              ATTENUATION FOR THE INPUT CONDITIONS.
!  F          VARIABLE USED IN SUBPROGRAM ATTENUATION.  IS THE
!              RATIO OF FREQUENCY TO FREQUENCY AT MAXIMUM ATTENUATION.
!  Fmax       FREQUENCY OF MAXIMUM ATTENUATION. USED IN SUBPROGRAM
!              ATTENUATION.
!  Freq       INPUT FREQUENCY OF ECHOSOUNDER.
!  H          VARIABLE USED IN INTEGRATION FOR EXCESS ATTENUATION.
!  Pstar      VARIABLE USED IN SUBPROGRAM ATTENUATION FOR INTERMEDIATE
!              CALCULATION.
!  Temp       INPUT TEMPERATURE IN DEGREES CELSIUS.
!  Tstar      INTERMEDIATE VALUE USED IN CALCULATION OF ATTENUATION
!              IN SUBPROGRAM ATTENUATION.
!  Wat_pres   ATMOSPHERIC WATER PRESSURE IN MILLIBARS.  INPUT BY
!              OPERATOR.
H=100*Wat_pres/Atom_pres
Tstar=(1.8*Temp+492)/519
Pstar=Atom_pres/1014
Fmax=(10+6600*H+44400*H*H)*Pstar/Tstar^.8
Att_max=.0078*Fmax*Tstar^(-2.5)*EXP(7.77*(1-1/Tstar))
F=Freq/Fmax
Atten=(Att_max/304.8)*((.18*F)^2+(2*F*F/(1+F*F))^2)^.5
Atten=(Atten+1.74E-10*Freq*Freq)/4.35
SUBEND
!
def FNYes(X$)
!THIS FUNCTION INTERPRETS THE OPERATORS RESPONSES TO YES NO QUESTIONS
!
!    INPUT     X$
!
!    OUTPUT    FNYes
```

```
!VARIABLES
!  Temp$       VARIABLE STRING USED IN FUNCTION YES.
!  X$          STRING PASSED TO FUNCTION YES TO DETERMINE OPERATOR
!               RESPONSE TO YES OR NO QUESTION.
     DIM Temp$[1]
     Temp$[1,1]=TRIM$(X$)
     SELECT Temp$
     CASE "Y","y"
          RETURN 1
     CASE "N","n"
          RETURN 2
     CASE " "
          RETURN 1
     CASE ELSE
          RETURN -2
     END SELECT
FNEND
!
  !
sub Semi_log(Freq,Xvar(*),L,Range(*),J)
!
!     THIS SUBROUTINE MAKES A SEMI-LOG PLOT OF DATA PASSED FROM THE
!MAIN PROGRAM.
!
!     INPUT
!               X AND Y VALUES TO BE PLOTTED
!     OUTPUT   SEMI-LOG PLOT
!
!VARIABLES
!  J           FIRST ORDER INDEX FOR ASSORTED LOOPS.
!  L           SECOND ORDER INDEX FOR ASSORTED LOOPS.
!  Xvar(*)     VALUE OF ARRAY OF X VALUES TO BE PLOTTED IN SUBPROGRAM Semi_

!
CLIP ON
FOR J=1 TO L STEP 1
     PLOT Xvar(J),LGT(Range(J))
NEXT J
LDIR PI/4
LORG 2
CSIZE 3,.6
LINE TYPE 1
MOVE Xvar(J-1),LGT(Range(J-1))
LABEL USING "K";Freq,"Hz"
SUBEND
```

APPENDIX C

COMPUTER PROGRAM 3

```
!FULLER, ROBERT        PROG_3       EFFICIENCY
!
!10 SEP 85
!
!
!*******PURPOSE*******
!
!     THIS PROGRAM WILL TAKE PARAMETERS OF AN ECHOSOUNDER AND
!ESTIMATE THE RANGE AS A FUNCTION OF EFFICIENCY OF THE THE TRANSDUCER.
!THE FOLLOWING INPUTS ARE REQUIRED:
!    ATMOSPHERIC DATA
!    1)ATOMOSPHERIC PRESSURE in millibars
!    2)SELECT ONE OF FOUR ATMOSPHERIC PROFILES FOR THE TEMPERATURE
!      STRUCTURE PROFILE.
!        a)FOR ONE PROFILE THE HEIGHT OF THE INVERSION LAYER IS ALSO INPUT
!    3)TEMPERATURE IN DEGREES CELSIUS
!    4)WATER VAPOR PRESSURE IN millibars
!
!    ECHOSOUNDER DATA
!    5)ANTENNA DIAMETER IN METERS
!    6)FREQUENCY
!    7)POWER TRANSMITTED BY ECHOSOUNDER IN WATTS
!    8)PULSE LENGTH OF THE TRANSMITTED ACOUSTIC ENERGY
!
!THE PROGRAM OUTPUTS THE FOLLOWING GRAPH TO AN EXTERNAL PLOTTER:
!    1)RANGE(m.) VERSUS EFFICIENCY OF ECHOSOUNDER
!
!
!*****VARIABLES*****
!
!
!  Again      TEST VALUE IN WHILE LOOP TO DETERMINE IF OPERATOR
!              WISHES TO MAKE ANOUTHER RUN.
!  Ano_change TEST VALUE IN WHILE LOOP TO DETERMINE IF OPERATOR
!              WISHES TO CHANGE THE VALUE OF INPUT DATA BEFORE MAKING
!              ANOUTHER RUN.
!  Ant_area   ECHOSOUNDER ANTENNA AREA CALCULATED FROM INPUT OF
!              ANTENNA DIAMETER.
!  Ant_diam   INPUT OF ECHOSOUNDER ANTENNA DIAMETER IN METERS.
!  Atom_pres  INPUT OF ATMOSPHERIC PRESSURE IN mb.
!  Atten      ATTENUATION OF ACOUSTIC WAVE.  CALCULATED IN
!              SUBPROGRAM ATTENUATION.
!  Bn         BANDWIDTH OF RECEIVER NEEDED TO RECEIVE SIGNALS
!              DOPPLER SHIFFED BY THREE METER PER SECOND
!              VERTICAL VELOCITIES.
!  C          VELOCITY OF SOUND CALCULATION AT ZERO CELSIUS.
!  C1         VARIABLE USED TO SCALE INVERSION HEIGHT IN
!              TEMPERATURE STRUCTURE PROFILE THREE.
!  C3         VARIABLE USED IN CALCULATING THE FOURTH Cte2 PROFILE.
!  Cne2(*)    ARRAY OF VALUES OF THE ACOUSTIC REFRACTIVE INDEX
```

```
!                PARAMETER.  CALCULATED BASED ON SELECTION OF
!                PROFILE FOR TEMPERATURE STRUCTURE PARAMETER
!                AND ASSUMED PROFILE FOR THE VELOCITY STRUCTURE
!                PARAMETER.
!   Cte2        VALUE OF THE TEMPERATURE STRUCTURE PARAMETER.
!                THE OPERATOR SELECTS A PROFILE FROM SEVERAL PROVIDED.
!   Cve2        VALUE OF THE VELOCITY STRUCTURE  PARAMETER.
!                VALUES BASED ON CALCULATION USING ASSUMED DISSAPATION
!                RATE.
!   Dx          STEP SIZE FOR X AXIS FOR VARIOUS PLOTS.
!   Dy          STEP SIZE FOR Y AXIS FOR VARIOUS PLOTS.
!   Epsilon     DISSAPATION RATE USED IN CALCULATION OF Cve2.
!   Eff         TRANSMISSION EFFICIENCY OF ECHOSOUNDER.
!   Eff         EFFICIENCY OF ECHOSOUNDER WHEN RECEIVING ACOUSTIC
!                BACKSCATTER.
!   Exc_att     EXCESS "ATTENUATION" AT GIVEN RANGE.
!   F           VARIABLE USED IN SUBPROGRAM ATTENUATION.  IS THE
!                RATIO OF FREQUENCY TO FREQUENCY AT MAXIMUM ATTENUATION.
!   Fmax        FREQUENCY OF MAXIMUM ATTENUATION. USED IN SUBPROGRAM
!                ATTENUATION.
!   Freq        INPUT FREQUENCY OF ECHOSOUNDER.
!   G           ANTENNA EFFECTIVE APERATURE FACTOR.
!   H           VARIABLE USED IN INTEGRATION FOR EXCESS ATTENUATION.
!   I           MAIN INDEX FOR LOOP TO CHECK RETURNED POWER UNTIL
!                POWER WAS LESS THAN MINIMUM DETECTABLE SIGNAL.
!   IND         INDEX USED FOR LOOP FOR DIFFERENT EFFICIENCIES
!   Interval    MAXIMUM EFFECTIVE-SCATTERING VOLUME THICKNESS.
!   Inver       HEIGHT OF INVERSION LAYER.
!   J           FIRST ORDER INDEX FOR ASSORTED LOOPS.
!   K           WAVENUMBER
!   L           SECOND ORDER INDEX FOR ASSORTED LOOPS.
!   Mess_up     TEST VALUE TO CHECK RESPONSES WHEN OPERATOR IS INPUTTING
!                RESPONSES.
!   N           TEST VALUE IN CALCULATION OF COHERENCE LENTH IN CALCULATION
!                OF EXCESS ATTENUATION.
!   New_va      TEST VALUE IN CHECKING IF OPERATOR WISHES TO CHANGE
!                A VARIABLE BEFORE A NEW RUN.
!   Noise       ASSUMED MINIMUM DETECTABLE SIGNAL.
!   Pow_back(*) POWER BACKSCATTERED FROM GIVEN RANGE.
!   Pow_ret(*)  POWER BACKSCATTERED TO ECHOSOUNDER FROM GIVEN RANGE.
!   Pow_trans   INPUT OF POWER SUPPLIED TO TRANSDUCER OF ECHOSOUNDER.
!   Profile     OPERATOR INPUT OF Cte2 PROFILE FROM AVAILABLE PROFILES.
!   Pstar       VARIABLE USED IN SUBPROGRAM ATTENUATION FOR INTERMEDIATE
!                CALCULATION.
!   Pulse       TRANSMITTED PULSE LENGTH IN MILLISECONDS.  INPUT BY
!                OPERATOR.
!   R           RANGE FOR INPUT TO INTEGRAL OF EXCESS ATTENUATION.
!   R1          VARIABLE USED IN SCALING INVERSION HEIGHT FOR PROFILE THREE.
!   Range(*)    ARRAY OF RANGE VALUES.
!   Remainder   REMAINDER OF MODULO FUNCTION USED TO DECREES THE
```

```
!               NUMBER OF PASSES THROUGH THE INTEGRATION FOR EXCESS
!               ATTENUATION.
!  Rge         VALUE OF RANGE IN INTEGRAL FOR EXCESS ATTENUATION.
!  Rho         CORRELATION LENGTH USED IN CALCULATION OF EXCESS
!               ATTENUATION.
!  Sigma       FRACTION OF ENERGY BACKSCATTERED FROM GIVEN RANGE.
!  Speed_sound SPEED OF SOUND IN AIR AT INPUT TEMPERATURE.
!  Sumpow_back
!  T           INPUT TEMPERATURE IN DEGREES KELVIN.
!  Temp        INPUT TEMPERATURE IN DEGREES CELSIUS.
!  Temp$       VARIABLE STRING USED IN FUNCTION YES.
!
!  Tstar       INTERMEDIATE VALUE USED IN CALCULATION OF ATTENUATION
!               IN SUBPROGRAM ATTENUATION.
!  Var         USED TO SELECT THE VARIABLE THE OPERATOR WISHED TO
!               CHANGE BEFORE MAKING ANOTHER RUN.
!  Wat_pres    ATMOSPHERIC WATER PRESSURE IN MILLIBARS.  INPUT BY
!               OPERATOR.
!  X           THIRD ORDER INDEX USED IN VARIOUS LOOPS.
!  X$          STRING PASSED TO FUNCTION YES TO DETERMINE OPERATOR
!               RESPONSE TO YES OR NO QUESTION.
!  Xmax        VALUE OF LARGEST VALUE OF X FOR VARIOUS PLOTS.
!  Xmin        VALUE OF SMALLEST VALUE OF X FOR VARIOUS PLOTS.
!  Xrange      VALUE OF RANGE OF X VALUES FOR VARIOUS PLOTS.
!  Ylabel$     LABEL ON Y AXIS PASSED TO SUBPROGRAM Semi_log FOR PLOTTING.
!  Ymax        LARGEST VALUE OF Y VARIABLE FOR VARIOUS PLOTS.
!  Ymin        SMALLEST VALUE OF Y VARIABLE FOR VARIOUS PLOTS.
!  Yrange      RANGE OF Y VARIABLES FOR VARIOUS PLOTS.
!  Ze          INTERMEDIATE VALUE IN CALCULATION OF EXCESS ATTENUATION.
!
!
!DECLARE VARIABLES
INTEGER I
DIM Pow_back(1500),Pow_ret(1500),Range(1500)
DIM Cne2(1500),Ran(30)
!
PLOTTER IS 705,"HPGL"
LINE TYPE 1
!
!INPUT ATMOSPHERIC DATA
INPUT "ENTER TEMPERATURE IN DEGREES CELCIUS",Temp
INPUT "ENTER ATMOSPHERIC PRESSURE IN MILLIBARS",Atom_pres
INPUT "ENTER WATER VAPOR PRESSURE IN MILLIBARS",Wat_pres
!
!
!INPUT ECHOSOUNDER DATA
INPUT "ENTER ANTENNA DIAM IN METERS",Ant_diam
INPUT "ENTER ECHOSOUNDER FREQUENCY IN HERTZ",Freq
INPUT "ENTER ECHOSOUNDER PULSE LENGTH IN MILLISECONDS=",Pulse
INPUT "ENTER POWER TO TRANSMITTER IN WATTS",Pow_trans
```

```
G=.40          !ANTENNA EFFECTIVE APERATURE FACTOR
!
!
!SELECT THE PROFILE FOR THE TEMPERATURE STRUCTURE
PRINT "YOU HAVE A CHOICE OF TEMPERATURE STRUCTURE PROFILES"
PRINT "PROFILE TO BE USED."
PRINT "YOUR SELECTIONS ARE"
PRINT "      1       A TEMPERARURE STRUCTURE PROFILE BASED ON DATA AS "
PRINT "              PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398 WHICH "
PRINT "               GIVES A HEIGHT TO THE -1.16 PROFILE"
PRINT " "
PRINT "      2       THE TEMPERATURE STRUCTURE PROFILE ABOVE BUT"
PRINT "              WITH A FACTOR OF TWO TO APPROXIMATE LOOKING"
PRINT "              UP A THERMAL PLOOM"
PRINT " "
PRINT "      3       A TEMPERATURE STRUCTURE PROFILE BASED ON DATA AS"
PRINT "              PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398 FOR"
PRINT "              NIGHT CONDITIONS.  THE DEPENDENCE WITH HEIGHT "
PRINT "              IS EXP(-.001*HEIGHT ABOVE 65 METERS AND HEIGHT"
PRINT "              TO THE -1.46 BELOW 65 METERS"
PRINT " "
PRINT "      4       A TEMPERATURE STRUCTURE PROFILE BASED ON A"
PRINT "               HEIGHT TO THE -4/3 "
!
PRINT " "
PRINT " "
Mess_up=1
WHILE Mess_up=1
     INPUT "ENTER THE DESIRED PROFILE (1 OR 2 OR 3 OR 4)",Profile
     IF Profile=4 THEN
          INPUT "ENTER THE HEIGHT OF THE INVERSION IN METERS",Inver
     END IF
     IF Profile=1 THEN
         Mess_up=0
     ELSE
         IF Profile=2 THEN
              Mess_up=0
         ELSE
              IF Profile=3 THEN
                   Mess_up=0
              ELSE
                   IF Profile=4 THEN
                        Mess_up=0
                   ELSE
                        PRINT Profile," WAS NOT ONE OF THE OPTIONS!!!!"
                        Mess_up=1
                   END IF
              END IF
         END IF
      END IF
```

```
END WHILE
OUTPUT KBD;"K";
!
!
Again=1
WHILE Again=1
  FOR J=1 TO I
     Pow_back(J)=0
     Pow_ret(J)=0
     Range(J)=0
     Cne2(J)=0
  NEXT J
  !
  !CONVERT TEMPERATURE TO KELVIN
  T=Temp+273
  !
  !CALCULATE SPEED OF SOUND BASED ON INPUT TEMPERATURE(CELCIUS)
  Speed_sound=20.05*(T)^.5
  !CALCULATE THE SPEED OF SOUND AT 0 DEGREES CELCIUS
  C=20.05*273^.5
  !
  I=1    !INDEX FOR INNER LOOP (POWER RETURNED TO NOISE)
  Ind=1  !INDEX FOR OUTER LOOP (EFFICIENCY)
  Pow_back(0)=0    !INITIALIZE VARIABLE FOR POWER BACKSCATERRED
  Ant_area=PI*(Ant_diam/2)^2   !ANTENNA AREA
  Interval=(Speed_sound*Pulse*1.E-3)/2
  !
  !INITIALIZE PLOTTING PARAMETERS SO CAN COMPARE DURING RUN TO SCALE
  !PLOTS
  Ymin=1000
  Ymax=0
  !CALCULATE RETURNED SIGNAL POWER UNTIL IT IS LESS THAN BACKGROUND
  !FOR EACH FREQUENCY.
  Range(0)=0
  FOR Eff=.05 TO .5 STEP .05
   Bn=2*Freq*(1-1/(6/Speed_sound+1))!BANDWIDTH FOR 3M/S VERTICAL VELOCITY
   Noise=1.38E-23*Bn*(T)+2.E-14!MINIMUM DETECTABLE SIGNAL AS
   !     JOHNSON NOISE(NEGLIGABLE)+ ESTIMATED BACKGROUND
   !CALCULATE THE ATTENUATION COEFFICIENT BASED ON ATMOSPHERIC DATA
   CALL Attenuation(Atom_pres,Atten,Freq,Temp,Wat_pres)
   K=2*PI*Freq/Speed_sound    !WAVENUMBER
   I=1
   Sumpow_back=0
   REPEAT
     Range(I)=Range(I-1)+2
     SELECT Profile
           CASE 1
           !THIS TEMPERATURE STRUCTURE PROFILE IS BASED UPON DATA
           !AS PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398.
           !WAS FOR MIDDAY AND CLEAR WEATHER ABOVE THE
```

```
        !TULAROSA BASIN, NEW MEXICO.
        !AN ADDITONAL FACTOR OF 1.8 WAS INCLUDED AS PER DIFFERENT
        !AVERAGING TIME.
            Cte2=2.12*Range(I)^(-1.16)
        CASE 2
        !THIS TEMPERATURE STRUCTURE PROFILE IS BASED UPON DATA
        !AS PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398.
        !WAS FOR MIDDAY AND CLEAR WEATHER ABOVE THE
        !TULAROSA BASIN, NEW MEXICO.
        !AN ADDITONAL FACTOR OF 1.8 WAS INCLUDED AS PER DIFFERENT
        !AVERAGING TIME AND AN ADDITIONAL FACTOR OF TWO WAS
        !INCLUDED TO APPROXIMATE LOOKING UP A THERMAL PLOOM
            Cte2=2*2.12*Range(I)^(-1.16)
        CASE 3
        !THIS TEMPERATURE STRUCTURE PROFILE BASED ON DATA AS"
        !PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398 FOR"
        !NIGHT CONDITIONS.  THE DEPENDENCE WITH HEIGHT "
        !IS EXP(-.001*HEIGHT ABOVE 65 METERS AND HEIGHT"
        !TO THE -1.46 BELOW 65 METERS"
            IF Range(I)<65 THEN
                 Cte2=75.5*Range(I)^(-1.46)
            ELSE
                 Cte2=3.66E-2*EXP(-.001*Range(I))
            END IF
        CASE 4
        !CALCULATE THE TEMPERATURE STRUCTURE FACTOR BASED ON ASSUMPTION
        !    THAT IT'S PROPORTIONAL TO HEIGHT TO THE -4/3 POWER
        !    THAT THE SURFACE VERTICAL HEAT FLUX IS .095 C.m./sec
        !THE DEPENDENCE WITH HEIGHT ABOVE THE INVERSION I PULLED FROM
        !MY LEFT EAR
        !EQUATION FROM NEFF, 1975
        SELECT Range(I)/Inver
             CASE <.9
                 C3=((.024)*(T)^(.667))
                 Cte2=C3*(Range(I))^(-1.33)
             CASE .9 TO 1
                 Cte2=Cte2
                 C1=Cte2
                 R1=Range(I)
             CASE 1 TO 1.3
                 Cte2=10^((LGT(C3*Range(I))-LGT(C3*R1))+LGT(C1))
                 R2=Range(I)
                 C2=Cte2
             CASE ELSE
                 Cte2=C3*(Range(I)^(-1.33)-R2^(-1.33))+C2
        END SELECT
   END SELECT
   !CALCULATE VELOCITY STRUCTURE FACTOR. FORMULA FROM GAYNOR 77
   Epsilon=(.2866/Range(I))*(1+.07*(Range(I))^(.6))^(1.5)
   Cve2=2*Epsilon^(.667)
```

```
!CALCULATE ACOUSTIC REFRACTIVE INDEX STRUCTURE FACTOR.
!FORMULA FROM TETARSKI
Cne2(I)=(Cte2/(2.98E+5))+(Cve2/(C*C))
!CALCULATE THE FRACTION OF POWER BACKSCATTERED FROM INTERVAL.
!EQUATION FROM NEFF, 1975
Sigma=(.0039*(K^(1/3))*Cte2)/(T)^2
!
!CALCULATE THE EXCESS ATTENUATION.  EQUATION FROM CLIFFORD, 1980
!THE EXCESS ATTENUATION IS Exc_att
IF I<50 THEN
     Remainder=0
ELSE
     IF I<150 THEN
          Remainder=Range(I) MODULO 10
     ELSE
          Remainder=Range(I) MODULO 20
     END IF
END IF
IF Remainder=0 THEN
     Rho=0
     L=0
     H=0
     Rge=Range(I)     !CONSTANT IN INTEGRAL
     R=0
     FOR J=0 TO 2*I
               F=Cne2(INT(J/2+1))
               F=F*(1-R/(Rge)^(1.67)+(R/(Rge))^(1.67))
               IF J>0 THEN
                    IF J<2*I THEN
                         IF INT(J/2)=J/2 THEN
                              L=L+F
                              F=0
                         ELSE
                              H=H+F
                              F=0
                         END IF
                    END IF
               END IF
               Rho=Rho+F
               R=R+1
     NEXT J
     Rho=Rho+4*L+2*H
     Rho=(((Rho*.33)*K*K*1.46)^(-.6))
     N=(Ant_diam/Rho)^2
     IF N<=1 THEN
          Ze=1/(1+N)
     ELSE
          Ze=1.5/(1+N)
          !STEP OF 1.5==>SEE CLIFFORD 1980
     END IF
```

```
            Exc_att=Ze*Ze
        ELSE
            Exc_att=Exc_att
        END IF
        !
        !CALCULATE THE POWER BACKSCATTERED
        Pow_back(I)=(Pow_trans*Eff-Sumpow_back)*EXP(-Atten*Range(I))
        Pow_back(I)=Pow_back(I)*Interval*Exc_att*Sigma
        Sumpow_back=Sumpow_back+Pow_back(I)
        !CALCULATE THE POWER BACKSCATTERED TO THE ANTENNA
       Pow_ret(I)=Pow_back(I)*EXP(-Atten*Range(I))*Ant_area*G*Eff/Range(I)^2
        PRINT "RANGE=",Range(I)
        PRINT "POWER RETURNED=",Pow_ret(I)
        I=I+1
  UNTIL Pow_ret(I-1)>0 AND Pow_ret(I-1)<=Noise
  Ran(Ind)=Range(I-2)
  IF Range(I-2)>Ymax THEN
      Ymax=Range(I-2)
  END IF
  IF Range(I-2)<Ymin THEN
      Ymin=Range(I-2)
  END IF
  Ind=Ind+1
  Again=1
  FOR J=1 TO I
     Pow_back(J)=0
     Pow_ret(J)=0
     Range(J)=0
     Cne2(J)=0
  NEXT J
NEXT Eff
!
!
OUTPUT KBD;"K";
PRINT "INPUT CONDITIONS"
!
PRINT " "
PRINT USING "K";"TEMPERATURE=               ",Temp,"CELCIUS"
PRINT USING "K";"ATMOSPHERIC PRESSURE=      ",Atom_pres,"mb"
PRINT USING "K";"WATER VAPOR PRESSURE=      ",Wat_pres,"mb"
PRINT USING "K";"PULSE LENGTH=              ",Pulse,"ms"
PRINT USING "K";"ANTENNA DIAMETER=          ",Ant_diam," m."
PRINT USING "K";"ECHOSOUNDER FREQUENCY=     ",Freq,"Hz"
PRINT USING "K";"POWER TRANSMITTED=         ",Pow_trans," WATTS"
PRINT "TEMPERATURE STRUCTURE PROFILE USED ",Profile
IF Profile=4 THEN
   PRINT "INVERSION HEIGHT ",Inver
END IF
SELECT Profile
   CASE 1
```

```
        PRINT "     1      A TEMPERARURE STRUCTURE PROFILE BASED ON DATA"
        PRINT "            AS PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398 "
        PRINT "            WHICH GIVES A HEIGHT TO THE -1.16 PROFILE"
    CASE 2
        PRINT "     2      A TEMPERARURE STRUCTURE PROFILE BASED ON DATA"
        PRINT "            AS PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398 "
        PRINT "            WHICH GIVES A HEIGHT TO THE -1.16 PROFILE"
        PRINT "            BUT WITH A FACTOR OF TWO TO APPROXIMATE"
        PRINT "            LOOKING UP A THERMAL PLOOM"
    CASE 3
        PRINT "     3      A TEMPERATURE STRUCTURE PROFILE BASED ON DATA"
        PRINT "            AS PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398"
        PRINT "            FOR NIGHT CONDITIONS.  THE DEPENDENCE WITH"
        PRINT "            HEIGHT IS EXP(-.001*HEIGHT ABOVE 65 METERS"
        PRINT "            AND HEIGHT TO THE -1.46 BELOW 65 METERS"
    CASE 4
        PRINT "     4      A TEMPERATURE STRUCTURE PROFILE BASED ON A"
        PRINT "             HEIGHT TO THE -4/3 "
END SELECT
!
PRINT USING "K";"THE MINIMUM DETECTABLE SIGNAL WAS SET AT",Noise,"WATTS"
!
PRINT " "
!
!
PRINT "HIT CONTINUE TO CONTINUE"
PAUSE
OUTPUT KBD;"K";
!
GRAPHICS ON
VIEWPORT 15,120,10,70
!
!
!PLOT RANGE VERSUS FREQUENCY
Xmin=0
Xmax=.5
Ymin=PROUND(Ymin-50,2)
Ymax=PROUND(Ymax+50,2)
Dx=.05
Dy=100
Xrange=Xmax-Xmin
Yrange=Ymax-Ymin
WINDOW Xmin,Xmax,Ymin,Ymax
AXES Dx,Dy,Xmin,Ymin,2,1
CLIP OFF
!
!LABEL PLOT
CSIZE 4,.6
LDIR 0
LORG 5
```

```
MOVE .5*Xrange,Ymax*1.05
LABEL "RANGE VERSUS TRANSDUCER EFFICIENCY"
!LABEL HORIZONTAL AXES
LDIR 0
LORG 5
FOR J=0 TO Xmax STEP Dx
   CSIZE 4,.6
   MOVE J,Ymin-.05*Yrange
   LABEL J
NEXT J
MOVE .5*Xrange,Ymin-.1*Yrange
CSIZE 4,.6
LABEL "EFFICIENCY"
!LABEL VERTICAL AXES
LORG 8
FOR J=Ymin TO Ymax STEP Dy
   CSIZE 4,.6
   MOVE Xmin-.0025*Xrange,J
   LABEL USING "K";J
NEXT J
LDIR PI/2
LORG 6
MOVE Xmin-.15*Xrange,.5*Yrange+Ymin
CSIZE 4,.6
LABEL "RANGE (METERS)"
CLIP ON
Ind=1
FOR Eff=.05 TO .5 STEP .05
   PLOT Eff,Ran(Ind)
   Ind=Ind+1
NEXT Eff
!
PRINT "HIT CONTINUE TO CONTINUE"
PAUSE
GCLEAR
OUTPUT KBD;"K";
!
!
LINPUT "WOULD YOU LIKE TO MAKE ANOTHER RUN (ENTER Y OR N)?",X$
Again=FNYes(X$)
Mess_up=1
WHILE Mess_up=1
 SELECT Again
   CASE 1
       LINPUT "WOULD YOU LIKE TO CHANGE A VARIABLE (ENTER Y OR N)?",X$
        New_va=FNYes(X$)
        Ano_change=1
        WHILE Ano_change=1
          SELECT New_va
             CASE 1
```

```
PRINT "       VARIABLE            CURRENT VALUE"
PRINT USING "K";"1  TEMPERATURE          ",Temp,"CELSIUS"
PRINT USING "K";"2  ATOMOSPHERIC PRESSURE ",Atom_pres,"mb"
PRINT USING "K";"3  WATER VAPOR PRESSURE ",Wat_pres,"mb"
PRINT " "
PRINT USING "K";"4  ANTENNA DIAMETER     ",Ant_diam," m."
PRINT USING "K";"5  PULSE LENGTH         ",Pulse," ms"
PRINT USING "K";"6  POWER TRANSMITTED ",Pow_trans," WATTS"
PRINT USING "K";"7  ATMOSPHERIC PROFILE  ",Profile
PRINT " "
PRINT "ENTER THE NUMBER OF THE VARIABLE YOU WISH TO"
PRINT "CHANGE"
INPUT Var
SELECT Var
        CASE 1
           INPUT "TEMPERATURE=",Temp
        CASE 2
           INPUT "ATMOSPHERIC PRESSURE IN mb=",Atom_pres
        CASE 3
           INPUT "WATER VAPOR PRESSURE IN mb=",Wat_pres
        CASE 4
           INPUT "ANTENNA DIAMETER IN m.=",Ant_diam
        CASE 5
           INPUT "PULSE LENGTH IN ms=",Pulse
        CASE 6
           INPUT "POWER TRANSMITTED IN WATTS=",Pow_trans
        CASE 7
          PRINT " 1  ==> Ct^2 PROFILE OF Z^(-1.16)"
          PRINT "        FROM WALTERS/KUNDEL 1981"
          PRINT " 2  ==> SAME AS ONE BUT WITH FACTOR"
          PRINT "        OF TWO TO APPROXIMATE LOOKING"
          PRINT "        UP A THERMAL PLOOM"
          PRINT " 3  ==> Ct^2 PROFILE OF EXP(-.001*Z)"
          PRINT "        FROM WALTERS/KUNDEL 1981."
          PRINT " 4  ==> CT^2 PROFILE OF Z^(-4/3)"
          INPUT "ENTER NUMBER OF DESIRED PROFILE",Profile
          IF Profile=4 THEN
           INPUT "HEIGHT OF INVERSION IN METERS=",Inver
          END IF
        CASE ELSE
          PRINT Var,"IS NOT ONE OF THE OPTIONS"
    END SELECT
    LINPUT "MADE ANOTHER CHANGE(ENTER Y OR N)?",X$
    New_va=FNYes(X$)
    Mess_up=2
CASE 2
    Mess_up=2
    Ano_change=2
CASE ELSE
    PRINT "YOUR CHOICES WHERE Y OR N !!!!!"
```

```
                    Ano_change=1
                    LINPUT "CHANGE A VARIABLE (ENTER Y OR N)?",X$
                    New_va=FNYes(X$)
               END SELECT
             END WHILE
         CASE 2
             Mess_up=2
         CASE ELSE
             PRINT "YOUR CHOICES WHERE Y OR N  !!!!!!"
             Mess_up=1
             LINPUT "MAKE ANOTHER RUN (ENTER Y OR N)?",X$
             Again=FNYes(X$)
       END SELECT
     END WHILE
END WHILE
PRINT "THAT'S ALL, FOLKS"
end
!
!
!CALCULTE THE ATTENUATION
sub Attenuation(Atom_pres,Atten,Freq,Temp,Wat_pres)
!THIS SUBPROGRAM CALCULATES THE ATTENUATION OF SOUND
!IN AIR BASED UPON EQUATIONS IN NEFF 1975
!
!    INPUT   ATMOSPHERIC PRESSURE IN MILLIBARS
!            FREQUENCY OF SOUND WAVE IN HERTZ
!            TEMPERATURE IN DEGREES CELCIUS
!            WATER-VAPOR PRESSURE IN MILLIBARS
!
!    OUTPUT  ATTENUATION IN 1/METERS
!
!VARIABLES
!   Atom_pres  INPUT OF ATMOSPHERIC PRESSURE IN mb.
!   Atten      ATTENUATION OF ACOUSTIC WAVE.  CALCULATED IN
!               SUBPROGRAM ATTENUATION.
!   Att_max    VARIABLE IN SUBPROGRAM ATTENUATION.  IT IS THE
!               ATTENUATION AT THE FREQUENCY OF THE MAXIMUM
!               ATTENUATION FOR THE INPUT CONDITIONS.
!   F          VARIABLE USED IN SUBPROGRAM ATTENUATION.  IS THE
!               RATIO OF FREQUENCY TO FREQUENCY AT MAXIMUM ATTENUATION.
!   Fmax       FREQUENCY OF MAXIMUM ATTENUATION. USED IN SUBPROGRAM
!               ATTENUATION.
!   Freq       INPUT FREQUENCY OF ECHOSOUNDER.
!   H          VARIABLE USED IN INTEGRATION FOR EXCESS ATTENUATION.
!   Pstar      VARIABLE USED IN SUBPROGRAM ATTENUATION FOR INTERMEDIATE
!               CALCULATION.
!   Temp       INPUT TEMPERATURE IN DEGREES CELSIUS.
!   Tstar      INTERMEDIATE VALUE USED IN CALCULATION OF ATTENUATION
!               IN SUBPROGRAM ATTENUATION.
!   Wat_pres   ATMOSPHERIC WATER PRESSURE IN MILLIBARS.  INPUT BY
```

```
!                 OPERATOR.
H=100*Wat_pres/Atom_pres
Tstar=(1.8*Temp+492)/519
Pstar=Atom_pres/1014
Fmax=(10+6600*H+44400*H*H)*Pstar/Tstar^.8
Att_max=.0078*Fmax*Tstar^(-2.5)*EXP(7.77*(1-1/Tstar))
F=Freq/Fmax
Atten=(Att_max/304.8)*((.18*F)^2+(2*F*F/(1+F*F))^2)^.5
Atten=(Atten+1.74E-10*Freq*Freq)/4.35
SUBEND
!
def FNYes(X$)
!THIS FUNCTION INTERPRETS THE OPERATORS RESPONSES TO YES NO QUESTIONS
!
!     INPUT      X$
!
!     OUTPUT     FNYes
!VARIABLES
!   Temp$       VARIABLE STRING USED IN FUNCTION YES.
!   X$          STRING PASSED TO FUNCTION YES TO DETERMINE OPERATOR
!                RESPONSE TO YES OR NO QUESTION.
     DIM Temp$[1]
     Temp$[1,1]=TRIM$(X$)
     SELECT Temp$
     CASE "Y","y"
          RETURN 1
     CASE "N","n"
          RETURN 2
     CASE " "
          RETURN 1
     CASE ELSE
          RETURN -2
     END SELECT
FNEND
!
```

APPENDIX D

COMPUTER PROGRAM 4

```
!FULLER, ROBERT        PROG_4        ANTENNA SIZE
!
!10 SEP 85
!
!
!*******PURPOSE*******
!
!     THIS PROGRAM WILL TAKE PARAMETERS OF AN ECHOSOUNDER AND
!ESTIMATE THE RANGE AS A FUNCTION OF ANTENNA SIZE OF THE THE ECHOSOUNDER.
!THE FOLLOWING INPUTS ARE REQUIRED:
!    ATMOSPHERIC DATA
!    1)ATOMOSPHERIC PRESSURE in millibars
!    2)SELECT ONE OF FOUR ATMOSPHERIC PROFILES FOR THE TEMPERATURE
!      STRUCTURE PROFILE.
!       a)FOR ONE PROFILE THE HEIGHT OF THE INVERSION LAYER IS ALSO INPUT
!    3)TEMPERATURE IN DEGREES CELSIUS
!    4)WATER VAPOR PRESSURE IN millibars
!
!    ECHOSOUNDER DATA
!    5)FREQUENCY
!    6)POWER TRANSMITTED BY ECHOSOUNDER IN WATTS
!    7)PULSE LENGTH OF THE TRANSMITTED ACOUSTIC ENERGY
!
!THE PROGRAM OUTPUTS THE FOLLOWING GRAPH TO AN EXTERNAL PLOTTER:
!    1)RANGE(m.) VERSUS ANTENNA DIAMETER FOR VARIOUS FREQUENCIES
!
!
!*****VARIABLES*****
!
!
!  Again      TEST VALUE IN WHILE LOOP TO DETERMINE IF OPERATOR
!              WISHES TO MAKE ANOUTHER RUN.
!  Ano_change TEST VALUE IN WHILE LOOP TO DETERMINE IF OPERATOR
!              WISHES TO CHANGE THE VALUE OF INPUT DATA BEFORE MAKING
!              ANOUTHER RUN.
!  Ant_area   ECHOSOUNDER ANTENNA AREA CALCULATED FROM INPUT OF
!              ANTENNA DIAMETER.
!  Ant_diam   INPUT OF ECHOSOUNDER ANTENNA DIAMETER IN METERS.
!  Atom_pres  INPUT OF ATMOSPHERIC PRESSURE IN mb.
!  Atten      ATTENUATION OF ACOUSTIC WAVE.  CALCULATED IN
!              SUBPROGRAM ATTENUATION.
!  Bn         BANDWIDTH OF RECEIVER NEEDED TO RECEIVE SIGNALS
!              DOPPLER SHIFFED BY THREE METER PER SECOND
!              VERTICAL VELOCITIES.
!  C          VELOCITY OF SOUND CALCULATION AT ZERO CELSIUS.
!  C1         VARIABLE USED TO SCALE INVERSION HEIGHT IN
!              TEMPERATURE STRUCTURE PROFILE THREE.
!  C3         VARIABLE USED IN CALCULATING THE FOURTH Cte2 PROFILE.
!  Cne2(*)    ARRAY OF VALUES OF THE ACOUSTIC REFRACTIVE INDEX
!              PARAMETER.  CALCULATED BASED ON SELECTION OF
```

```
!               PROFILE FOR TEMPERATURE STRUCTURE PARAMETER
!               AND ASSUMED PROFILE FOR THE VELOCITY STRUCTURE
!               PARAMETER.
!  Cte2        VALUE OF THE TEMPERATURE STRUCTURE PARAMETER.
!               THE OPERATOR SELECTS A PROFILE FROM SEVERAL PROVIDED.
!  Cve2        VALUE OF THE VELOCITY STRUCTURE  PARAMETER.
!               VALUES BASED ON CALCULATION USING ASSUMED DISSAPATION
!               RATE.
!  Dx          STEP SIZE FOR X AXIS FOR VARIOUS PLOTS.
!  Dy          STEP SIZE FOR Y AXIS FOR VARIOUS PLOTS.
!  Epsilon     DISSAPATION RATE USED IN CALCULATION OF Cve2.
!  Eff         TRANSMISSION EFFICIENCY OF ECHOSOUNDER.
!  Eff         EFFICIENCY OF ECHOSOUNDER WHEN RECEIVING ACOUSTIC
!               BACKSCATTER.
!  Exc_att     EXCESS "ATTENUATION" AT GIVEN RANGE.
!  F           VARIABLE USED IN SUBPROGRAM ATTENUATION.  IS THE
!               RATIO OF FREQUENCY TO FREQUENCY AT MAXIMUM ATTENUATION.
!  Fmax        FREQUENCY OF MAXIMUM ATTENUATION. USED IN SUBPROGRAM
!               ATTENUATION.
!  Freq        INPUT FREQUENCY OF ECHOSOUNDER.
!  G           ANTENNA EFFECTIVE APERATURE FACTOR.
!  H           VARIABLE USED IN INTEGRATION FOR EXCESS ATTENUATION.
!  I           MAIN INDEX FOR LOOP TO CHECK RETURNED POWER UNTIL
!               POWER WAS LESS THAN MINIMUM DETECTABLE SIGNAL.
!  IND         INDEX USED FOR LOOP FOR DIFFERENT EFFICIENCIES
!  Interval    MAXIMUM EFFECTIVE-SCATTERING VOLUME THICKNESS.
!  Inver       HEIGHT OF INVERSION LAYER.
!  J           FIRST ORDER INDEX FOR ASSORTED LOOPS.
!  K           WAVENUMBER
!  L           SECOND ORDER INDEX FOR ASSORTED LOOPS.
!  Mess_up     TEST VALUE TO CHECK RESPONSES WHEN OPERATOR IS INPUTTING
!               RESPONSES.
!  N           TEST VALUE IN CALCULATION OF COHERENCE LENTH IN CALCULATION
!               OF EXCESS ATTENUATION.
!  New_va      TEST VALUE IN CHECKING IF OPERATOR WISHES TO CHANGE
!               A VARIABLE BEFORE A NEW RUN.
!  Noise       ASSUMED MINIMUM DETECTABLE SIGNAL.
!  Pow_back(*) POWER BACKSCATTERED FROM GIVEN RANGE.
!  Pow_ret(*)  POWER BACKSCATTERED TO ECHOSOUNDER FROM GIVEN RANGE.
!  Pow_trans   INPUT OF POWER SUPPLIED TO TRANSDUCER OF ECHOSOUNDER.
!  Profile     OPERATOR INPUT OF Cte2 PROFILE FROM AVAILABLE PROFILES.
!  Pstar       VARIABLE USED IN SUBPROGRAM ATTENUATION FOR INTERMEDIATE
!               CALCULATION.
!  Pulse       TRANSMITTED PULSE LENGTH IN MILLISECONDS.  INPUT BY
!               OPERATOR.
!  R           RANGE FOR INPUT TO INTEGRAL OF EXCESS ATTENUATION.
!  R1          VARIABLE USED IN SCALING INVERSION HEIGHT FOR PROFILE THREE.
!  Range(*)    ARRAY OF RANGE VALUES.
!  Remainder   REMAINDER OF MODULO FUNCTION USED TO DECREES THE
!               NUMBER OF PASSES THROUGH THE INTEGRATION FOR EXCESS
```

```
!               ATTENUATION.
!  Rge          VALUE OF RANGE IN INTEGRAL FOR EXCESS ATTENUATION.
!  Rho          CORRELATION LENGTH USED IN CALCULATION OF EXCESS
!               ATTENUATION.
!  Sigma        FRACTION OF ENERGY BACKSCATTERED FROM GIVEN RANGE.
!  Speed_sound SPEED OF SOUND IN AIR AT INPUT TEMPERATURE.
!  Sumpow_back
!  T            INPUT TEMPERATURE IN DEGREES KELVIN.
!  Temp         INPUT TEMPERATURE IN DEGREES CELSIUS.
!  Temp$        VARIABLE STRING USED IN FUNCTION YES.
!
!  Tstar        INTERMEDIATE VALUE USED IN CALCULATION OF ATTENUATION
!               IN SUBPROGRAM ATTENUATION.
!  Var          USED TO SELECT THE VARIABLE THE OPERATOR WISHED TO
!               CHANGE BEFORE MAKING ANOTHER RUN.
!  Wat_pres     ATMOSPHERIC WATER PRESSURE IN MILLIBARS.  INPUT BY
!               OPERATOR.
!  X            THIRD ORDER INDEX USED IN VARIOUS LOOPS.
!  X$           STRING PASSED TO FUNCTION YES TO DETERMINE OPERATOR
!               RESPONSE TO YES OR NO QUESTION.
!  Xmax         VALUE OF LARGEST VALUE OF X FOR VARIOUS PLOTS.
!  Xmin         VALUE OF SMALLEST VALUE OF X FOR VARIOUS PLOTS.
!  Xrange       VALUE OF RANGE OF X VALUES FOR VARIOUS PLOTS.
!  Ylabel$      LABEL ON Y AXIS PASSED TO SUBPROGRAM Semi_log FOR PLOTTING.
!  Ymax         LARGEST VALUE OF Y VARIABLE FOR VARIOUS PLOTS.
!  Ymin         SMALLEST VALUE OF Y VARIABLE FOR VARIOUS PLOTS.
!  Yrange       RANGE OF Y VARIABLES FOR VARIOUS PLOTS.
!  Ze           INTERMEDIATE VALUE IN CALCULATION OF EXCESS ATTENUATION.
!
!
!DECLARE VARIABLES
INTEGER I
DIM Pow_back(1500),Pow_ret(1500),Range(1500)
DIM Cne2(1500),Ran(50,6)
!
PLOTTER IS 705,"HPGL"
LINE TYPE 1
!
!INPUT ATMOSPHERIC DATA
INPUT "ENTER TEMPERATURE IN DEGREES CELCIUS",Temp
INPUT "ENTER ATMOSPHERIC PRESSURE IN MILLIBARS",Atom_pres
INPUT "ENTER WATER VAPOR PRESSURE IN MILLIBARS",Wat_pres
!
!
!INPUT ECHOSOUNDER DATA
INPUT "ENTER ECHOSOUNDER PULSE LENGTH IN MILLISECONDS=",Pulse
INPUT "ENTER POWER TO TRANSMITTER IN WATTS",Pow_trans
G=.40          !ANTENNA EFFECTIVE APERATURE FACTOR
Eff=.25
!
```

```
        !TULAROSA BASIN, NEW MEXICO.
        !AN ADDITONAL FACTOR OF 1.8 WAS INCLUDED AS PER DIFFERENT
        !AVERAGING TIME.
            Cte2=2.12*Range(I)^(-1.16)
        CASE 2
        !THIS TEMPERATURE STRUCTURE PROFILE IS BASED UPON DATA
        !AS PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398.
        !WAS FOR MIDDAY AND CLEAR WEATHER ABOVE THE
        !TULAROSA BASIN, NEW MEXICO.
        !AN ADDITONAL FACTOR OF 1.8 WAS INCLUDED AS PER DIFFERENT
        !AVERAGING TIME AND AN ADDITIONAL FACTOR OF TWO WAS
        !INCLUDED TO APPROXIMATE LOOKING UP A THERMAL PLOOM
            Cte2=2*2.12*Range(I)^(-1.16)
        CASE 3
        !THIS TEMPERATURE STRUCTURE PROFILE BASED ON DATA AS"
        !PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398 FOR"
        !NIGHT CONDITIONS.  THE DEPENDENCE WITH HEIGHT "
        !IS EXP(-.001*HEIGHT ABOVE 65 METERS AND HEIGHT"
        !TO THE -1.46 BELOW 65 METERS"
            IF Range(I)<65 THEN
                Cte2=75.5*Range(I)^(-1.46)
            ELSE
                Cte2=3.66E-2*EXP(-.001*Range(I))
            END IF
        CASE 4
        !CALCULATE THE TEMPERATURE STRUCTURE FACTOR BASED ON ASSUMPTION
        !    THAT IT'S PROPORTIONAL TO HEIGHT TO THE -4/3 POWER
        !    THAT THE SURFACE VERTICAL HEAT FLUX IS .095 C.m./sec
        !THE DEPENDENCE WITH HEIGHT ABOVE THE INVERSION I PULLED FROM
        !MY LEFT EAR
        !EQUATION FROM NEFF, 1975
        SELECT Range(I)/Inver
            CASE <.9
                C3=((.024)*(T)^(.667))
                Cte2=C3*(Range(I))^(-1.33)
            CASE .9 TO 1
                Cte2=Cte2
                C1=Cte2
                R1=Range(I)
            CASE 1 TO 1.3
                Cte2=10^((LGT(C3*Range(I))-LGT(C3*R1))+LGT(C1))
                R2=Range(I)
                C2=Cte2
            CASE ELSE
                Cte2=C3*(Range(I)^(-1.33)-R2^(-1.33))+C2
        END SELECT
    END SELECT
    !CALCULATE VELOCITY STRUCTURE FACTOR. FORMULA FROM GAYNOR 77
    Epsilon=(.2866/Range(I))*(1+.07*(Range(I))^(.6))^(1.5)
    Cve2=2*Epsilon^(.667)
```

```
!CALCULATE ACOUSTIC REFRACTIVE INDEX STRUCTURE FACTOR.
!FORMULA FROM TETARSKI
Cne2(I)=(Cte2/(2.98E+5))+(Cve2/(C*C))
!CALCULATE THE FRACTION OF POWER BACKSCATTERED FROM INTERVAL.
!EQUATION FROM NEFF, 1975
Sigma=(.0039*(K^(1/3))*Cte2)/(T)^2
!
!CALCULATE THE EXCESS ATTENUATION.  EQUATION FROM CLIFFORD, 1980
!THE EXCESS ATTENUATION IS Exc_att
IF I<50 THEN
    Remainder=0
ELSE
    IF I<150 THEN
         Remainder=Range(I) MODULO 10
    ELSE
         Remainder=Range(I) MODULO 20
    END IF
END IF
IF Remainder=0 THEN
    Rho=0
    L=0
    H=0
    Rge=Range(I)    !CONSTANT IN INTEGRAL
    R=0
    FOR J=0 TO 2*I
              F=Cne2(INT(J/2+1))
              F=F*(1-R/(Rge)^(1.67)+(R/(Rge))^(1.67))
              IF J>0 THEN
                  IF J<2*I THEN
                       IF INT(J/2)=J/2 THEN
                            L=L+F
                            F=0
                       ELSE
                            H=H+F
                            F=0
                       END IF
                  END IF
              END IF
              Rho=Rho+F
              R=R+1
    NEXT J
    Rho=Rho+4*L+2*H
    Rho=(((Rho*.33)*K*K*1.46)^(-.6))
    N=(Ant_diam/Rho)^2
    IF N<=1 THEN
         Ze=1/(1+N)
    ELSE
         Ze=1.5/(1+N)
         !STEP OF 1.5==>SEE CLIFFORD 1980
    END IF
```

```
            Exc_att=Ze*Ze
        ELSE
            Exc_att=Exc_att
        END IF
        !
        !CALCULATE THE POWER BACKSCATTERED
        Pow_back(I)=(Pow_trans*Eff-Sumpow_back)*EXP(-Atten*Range(I))
        Pow_back(I)=Pow_back(I)*Interval*Exc_att*Sigma
        Sumpow_back=Sumpow_back+Pow_back(I)
        !CALCULATE THE POWER BACKSCATTERED TO THE ANTENNA
      Pow_ret(I)=Pow_back(I)*EXP(-Atten*Range(I))*Ant_area*G*Eff/Range(I)^2
        PRINT "RANGE=",Range(I)
        PRINT "POWER RETURNED=",Pow_ret(I)
        PRINT "FREQUENCY=",Freq
        I=I+1
     UNTIL Pow_ret(I-1)>0 AND Pow_ret(I-1)<=Noise
     Ran(Ind,Ifreq)=Range(I-2)
     IF Ran(Ind,Ifreq)>Ymax THEN
         Ymax=Ran(Ind,Ifreq)
     END IF
     IF Ran(Ind,Ifreq)<Ymin THEN
         Ymin=Ran(Ind,Ifreq)
     END IF
     Ind=Ind+1
     Again=1
     FOR J=0 TO I
        Pow_back(J)=0
        Pow_ret(J)=0
        Range(J)=0
        Cne2(J)=0
     NEXT J
    NEXT Ant_diam
    Ifreq=Ifreq+1
    Ind=1
  NEXT Freq
  !
  !
  OUTPUT KBD;"K";
  PRINT "INPUT CONDITIONS"
  !
  PRINT " "
  PRINT USING "K";"TEMPERATURE=                ",Temp,"CELCIUS"
  PRINT USING "K";"ATMOSPHERIC PRESSURE=       ",Atom_pres,"mb"
  PRINT USING "K";"WATER VAPOR PRESSURE=       ",Wat_pres,"mb"
  PRINT USING "K";"PULSE LENGTH=               ",Pulse,"ms"
  PRINT USING "K";"TRANSDUCER EFFICIENCY=      ",Eff
  PRINT USING "K";"POWER TRANSMITTED=          ",Pow_trans," WATTS"
  PRINT "TEMPERATURE STRUCTURE PROFILE USED ",Profile
  IF Profile=4 THEN
     PRINT "INVERSION HEIGHT ",Inver
```

```
END IF
SELECT Profile
   CASE 1
       PRINT "     1      A TEMPERARURE STRUCTURE PROFILE BASED ON DATA"
       PRINT "            AS PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398 "
       PRINT "            WHICH GIVES A HEIGHT TO THE -1.16 PROFILE"
   CASE 2
       PRINT "     2      A TEMPERARURE STRUCTURE PROFILE BASED ON DATA"
       PRINT "            AS PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398 "
       PRINT "            WHICH GIVES A HEIGHT TO THE -1.16 PROFILE"
       PRINT "            BUT WITH A FACTOR OF TWO TO APPROXIMATE"
       PRINT "            LOOKING UP A THERMAL PLOOM"
   CASE 3
       PRINT "     3      A TEMPERATURE STRUCTURE PROFILE BASED ON DATA"
       PRINT "            AS PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398"
       PRINT "            FOR NIGHT CONDITIONS.  THE DEPENDENCE WITH"
       PRINT "            HEIGHT IS EXP(-.001*HEIGHT ABOVE 65 METERS"
       PRINT "            AND HEIGHT TO THE -1.46 BELOW 65 METERS"
   CASE 4
       PRINT "     4      A TEMPERATURE STRUCTURE PROFILE BASED ON A"
       PRINT "             HEIGHT TO THE -4/3 "
END SELECT
!
PRINT USING "K";"THE MINIMUM DETECTABLE SIGNAL WAS SET AT",Noise,"WATTS"
!
PRINT " "
!
!
PRINT "HIT CONTINUE TO CONTINUE"
PAUSE
OUTPUT KBD;"K";
!
GRAPHICS ON
VIEWPORT 15,120,10,70
!
!
!PLOT RANGE VERSUS ANTENNA DIAMETER FOR VARIOUS FREQUENCIES
Xmin=0
Xmax=6
Ymin=PROUND(Ymin-50,2)
Ymax=PROUND(Ymax+50,2)
Dx=1
Dy=100
Xrange=Xmax-Xmin
Yrange=Ymax-Ymin
WINDOW Xmin,Xmax,Ymin,Ymax
AXES Dx,Dy,Xmin,Ymin,1,1
CLIP OFF
!
!LABEL PLOT
```

```
CSIZE 4,.6
LDIR 0
LORG 5
MOVE .5*Xrange,Ymax*1.05
LABEL "RANGE VERSUS ANTENNA DIAMETER"
!LABEL HORIZONTAL AXES
LDIR 0
LORG 5
FOR J=0 TO Xmax STEP Dx
   CSIZE 4,.6
   MOVE J,Ymin-.05*Yrange
   LABEL J
NEXT J
MOVE .5*Xrange,Ymin-.1*Yrange
CSIZE 4,.6
LABEL "ANTENNA DIAMETER (m.)"
!LABEL VERTICAL AXES
LORG 8
FOR J=Ymin TO Ymax STEP Dy
   CSIZE 4,.6
   MOVE Xmin-.0025*Xrange,J
   LABEL USING "K";J
NEXT J
LDIR PI/2
LORG 6
MOVE Xmin-.15*Xrange,.5*Yrange+Ymin
CSIZE 4,.6
LABEL "RANGE (METERS)"
CLIP ON
Ind=1
Ifreq=1
FOR Freq=500 TO 1500 STEP 500
  FOR Ant_diam=.5 TO 6.25-Ifreq STEP .25
     IF INT(Ifreq/2)=Ifreq/2 THEN
        LINE TYPE 3
     ELSE
        LINE TYPE 1
     END IF
     PLOT Ant_diam,Ran(Ind,Ifreq)
     Ind=Ind+1
  NEXT Ant_diam
  LDIR 0
  LORG 2
  CSIZE 3,.6
  MOVE Ant_diam-.1,Ran(Ind-1,Ifreq)
  LINE TYPE 1
  LABEL USING "K";Freq,"Hz"
  Ifreq=Ifreq+1
  Ind=1
NEXT Freq
```

```
!
PRINT "HIT CONTINUE TO CONTINUE"
PAUSE
GCLEAR
OUTPUT KBD;"K";
!
!
LINPUT "WOULD YOU LIKE TO MAKE ANOTHER RUN (ENTER Y OR N)?",X$
Again=FNYes(X$)
Mess_up=1
WHILE Mess_up=1
 SELECT Again
   CASE 1
       LINPUT "WOULD YOU LIKE TO CHANGE A VARIABLE (ENTER Y OR N)?",X$
        New_va=FNYes(X$)
        Ano_change=1
        WHILE Ano_change=1
          SELECT New_va
             CASE 1
              PRINT "       VARIABLE            CURRENT VALUE"
              PRINT USING "K";"1  TEMPERATURE          ",Temp,"CELSIUS"
              PRINT USING "K";"2  ATOMOSPHERIC PRESSURE ",Atom_pres,"mb"
              PRINT USING "K";"3  WATER VAPOR PRESSURE ",Wat_pres,"mb"
              PRINT " "
              PRINT USING "K";"4  ANTENNA DIAMETER      ",Ant_diam," m."
              PRINT USING "K";"5  PULSE LENGTH          ",Pulse," ms"
              PRINT USING "K";"6  POWER TRANSMITTED ",Pow_trans," WATTS"
              PRINT USING "K";"7  ATMOSPHERIC PROFILE  ",Profile
              PRINT " "
              PRINT "ENTER THE NUMBER OF THE VARIABLE YOU WISH TO"
              PRINT "CHANGE"
              INPUT Var
              SELECT Var
                     CASE 1
                        INPUT "TEMPERATURE=",Temp
                     CASE 2
                        INPUT "ATMOSPHERIC PRESSURE IN mb=",Atom_pres
                     CASE 3
                        INPUT "WATER VAPOR PRESSURE IN mb=",Wat_pres
                     CASE 4
                        INPUT "ANTENNA DIAMETER IN m.=",Ant_diam
                     CASE 5
                        INPUT "PULSE LENGTH IN ms=",Pulse
                     CASE 6
                        INPUT "POWER TRANSMITTED IN WATTS=",Pow_trans
                     CASE 7
                       PRINT " 1  ==> Ct^2 PROFILE OF Z^(-1.16)"
                       PRINT "        FROM WALTERS/KUNDEL 1981"
                       PRINT " 2  ==> SAME AS ONE BUT WITH FACTOR"
                       PRINT "        OF TWO TO APPROXIMATE LOOKING"
```

```
                                   PRINT "        UP A THERMAL PLOOM"
                                   PRINT " 3  ==> Ct^2 PROFILE OF EXP(-.001*Z)"
                                   PRINT "        FROM WALTERS/KUNDEL 1981."
                                   PRINT " 4  ==> CT^2 PROFILE OF Z^(-4/3)"
                                   INPUT "ENTER NUMBER OF DESIRED PROFILE",Profile
                                   IF Profile=4 THEN
                                    INPUT "HEIGHT OF INVERSION IN METERS=",Inver
                                   END IF
                                 CASE ELSE
                                   PRINT Var,"IS NOT ONE OF THE OPTIONS"
                            END SELECT
                            LINPUT "MADE ANOTHER CHANGE(ENTER Y OR N)?",X$
                            New_va=FNYes(X$)
                            Mess_up=2
                       CASE 2
                            Mess_up=2
                            Ano_change=2
                       CASE ELSE
                            PRINT "YOUR CHOICES WHERE Y OR N !!!!!"
                            Ano_change=1
                            LINPUT "CHANGE A VARIABLE (ENTER Y OR N)?",X$
                            New_va=FNYes(X$)
                  END SELECT
                END WHILE
            CASE 2
                Mess_up=2
            CASE ELSE
                PRINT "YOUR CHOICES WHERE Y OR N  !!!!!!"
                Mess_up=1
                LINPUT "MAKE ANOTHER RUN (ENTER Y OR N)?",X$
                Again=FNYes(X$)
          END SELECT
         END WHILE
      END WHILE
      PRINT "THAT'S ALL, FOLKS"
      end
      !
      !
      !CALCULTE THE ATTENUATION
      sub Attenuation(Atom_pres,Atten,Freq,Temp,Wat_pres)
      !THIS SUBPROGRAM CALCULATES THE ATTENUATION OF SOUND
      !IN AIR BASED UPON EQUATIONS IN NEFF 1975
      !
      !   INPUT    ATMOSPHERIC PRESSURE IN MILLIBARS
      !            FREQUENCY OF SOUND WAVE IN HERTZ
      !            TEMPERATURE IN DEGREES CELCIUS
      !            WATER-VAPOR PRESSURE IN MILLIBARS
      !
      !   OUTPUT   ATTENUATION IN 1/METERS
      !
```

```
!VARIABLES
!  Atom_pres  INPUT OF ATMOSPHERIC PRESSURE IN mb.
!  Atten      ATTENUATION OF ACOUSTIC WAVE.  CALCULATED IN
!              SUBPROGRAM ATTENUATION.
!  Att_max    VARIABLE IN SUBPROGRAM ATTENUATION.  IT IS THE
!              ATTENUATION AT THE FREQUENCY OF THE MAXIMUM
!              ATTENUATION FOR THE INPUT CONDITIONS.
!  F          VARIABLE USED IN SUBPROGRAM ATTENUATION.  IS THE
!              RATIO OF FREQUENCY TO FREQUENCY AT MAXIMUM ATTENUATION.
!  Fmax       FREQUENCY OF MAXIMUM ATTENUATION. USED IN SUBPROGRAM
!              ATTENUATION.
!  Freq       INPUT FREQUENCY OF ECHOSOUNDER.
!  H          VARIABLE USED IN INTEGRATION FOR EXCESS ATTENUATION.
!  Pstar      VARIABLE USED IN SUBPROGRAM ATTENUATION FOR INTERMEDIATE
!              CALCULATION.
!  Temp       INPUT TEMPERATURE IN DEGREES CELSIUS.
!  Tstar      INTERMEDIATE VALUE USED IN CALCULATION OF ATTENUATION
!              IN SUBPROGRAM ATTENUATION.
!  Wat_pres   ATMOSPHERIC WATER PRESSURE IN MILLIBARS.  INPUT BY
!              OPERATOR.
H=100*Wat_pres/Atom_pres
Tstar=(1.8*Temp+492)/519
Pstar=Atom_pres/1014
Fmax=(10+6600*H+44400*H*H)*Pstar/Tstar^.8
Att_max=.0078*Fmax*Tstar^(-2.5)*EXP(7.77*(1-1/Tstar))
F=Freq/Fmax
Atten=(Att_max/304.8)*((.18*F)^2+(2*F*F/(1+F*F))^2)^.5
Atten=(Atten+1.74E-10*Freq*Freq)/4.35
SUBEND
!
def FNYes(X$)
!THIS FUNCTION INTERPRETS THE OPERATORS RESPONSES TO YES NO QUESTIONS
!
!    INPUT     X$
!
!    OUTPUT    FNYes
!VARIABLES
!  Temp$      VARIABLE STRING USED IN FUNCTION YES.
!  X$         STRING PASSED TO FUNCTION YES TO DETERMINE OPERATOR
!              RESPONSE TO YES OR NO QUESTION.
     DIM Temp$[1]
     Temp$[1,1]=TRIM$(X$)
     SELECT Temp$
     CASE "Y","y"
          RETURN 1
     CASE "N","n"
          RETURN 2
     CASE " "
          RETURN 1
     CASE ELSE
```

```
            RETURN -2
        END SELECT
    FNEND
    !
```

APPENDIX E

COMPUTER PROGRAM 5

```
!FULLER, ROBERT       PROG_5        POWER
!
!10 SEP 85
!
!
!*******PURPOSE*******
!
!     THIS PROGRAM WILL TAKE PARAMETERS OF AN ECHOSOUNDER AND
!ESTIMATE THE RANGE AS A FUNCTION OF POWER TRANSMITTED BY THE ECHOSOUNDER
!FOR A RANGE OF FREQUIENCIES
!THE FOLLOWING INPUTS ARE REQUIRED:
!    ATMOSPHERIC DATA
!    1)ATOMOSPHERIC PRESSURE in millibars
!    2)SELECT ONE OF FOUR ATMOSPHERIC PROFILES FOR THE TEMPERATURE
!      STRUCTURE PROFILE.
!        a)FOR ONE PROFILE THE HEIGHT OF THE INVERSION LAYER IS ALSO INPUT
!    3)TEMPERATURE IN DEGREES CELSIUS
!    4)WATER VAPOR PRESSURE IN millibars
!
!    ECHOSOUNDER DATA
!    5)FREQUENCY
!    6)ANTENNA DIAMETER IN METERS
!    7)PULSE LENGTH OF THE TRANSMITTED ACOUSTIC ENERGY
!
!THE PROGRAM OUTPUTS THE FOLLOWING GRAPH TO AN EXTERNAL PLOTTER:
!    1)RANGE(m.) VERSUS POWER TRANSMITTED IN WATTS FOR VARIOUS FREQUENCIES
!
!
!*****VARIABLES*****
!
!
!  Again      TEST VALUE IN WHILE LOOP TO DETERMINE IF OPERATOR
!              WISHES TO MAKE ANOUTHER RUN.
!  Ano_change TEST VALUE IN WHILE LOOP TO DETERMINE IF OPERATOR
!              WISHES TO CHANGE THE VALUE OF INPUT DATA BEFORE MAKING
!              ANOUTHER RUN.
!  Ant_area   ECHOSOUNDER ANTENNA AREA CALCULATED FROM INPUT OF
!              ANTENNA DIAMETER.
!  Ant_diam   INPUT OF ECHOSOUNDER ANTENNA DIAMETER IN METERS.
!  Atom_pres  INPUT OF ATMOSPHERIC PRESSURE IN mb.
!  Atten      ATTENUATION OF ACOUSTIC WAVE.  CALCULATED IN
!              SUBPROGRAM ATTENUATION.
!  Bn         BANDWIDTH OF RECEIVER NEEDED TO RECEIVE SIGNALS
!              DOPPLER SHIFFED BY THREE METER PER SECOND
!              VERTICAL VELOCITIES.
!  C          VELOCITY OF SOUND CALCULATION AT ZERO CELSIUS.
!  C1         VARIABLE USED TO SCALE INVERSION HEIGHT IN
!              TEMPERATURE STRUCTURE PROFILE THREE.
!  C3         VARIABLE USED IN CALCULATING THE FOURTH Cte2 PROFILE.
!  Cne2(*)    ARRAY OF VALUES OF THE ACOUSTIC REFRACTIVE INDEX
```

```
!                PARAMETER.  CALCULATED BASED ON SELECTION OF
!                PROFILE FOR TEMPERATURE STRUCTURE PARAMETER
!                AND ASSUMED PROFILE FOR THE VELOCITY STRUCTURE
!                PARAMETER.
!  Cte2         VALUE OF THE TEMPERATURE STRUCTURE PARAMETER.
!                THE OPERATOR SELECTS A PROFILE FROM SEVERAL PROVIDED.
!  Cve2         VALUE OF THE VELOCITY STRUCTURE  PARAMETER.
!                VALUES BASED ON CALCULATION USING ASSUMED DISSAPATION
!                RATE.
!  Dx           STEP SIZE FOR X AXIS FOR VARIOUS PLOTS.
!  Dy           STEP SIZE FOR Y AXIS FOR VARIOUS PLOTS.
!  Epsilon      DISSAPATION RATE USED IN CALCULATION OF Cve2.
!  Eff          TRANSMISSION EFFICIENCY OF ECHOSOUNDER.
!  Eff          EFFICIENCY OF ECHOSOUNDER WHEN RECEIVING ACOUSTIC
!                BACKSCATTER.
!  Exc_att      EXCESS "ATTENUATION" AT GIVEN RANGE.
!  F            VARIABLE USED IN SUBPROGRAM ATTENUATION.  IS THE
!                RATIO OF FREQUENCY TO FREQUENCY AT MAXIMUM ATTENUATION.
!  Fmax         FREQUENCY OF MAXIMUM ATTENUATION. USED IN SUBPROGRAM
!                ATTENUATION.
!  Freq         INPUT FREQUENCY OF ECHOSOUNDER.
!  G            ANTENNA EFFECTIVE APERATURE FACTOR.
!  H            VARIABLE USED IN INTEGRATION FOR EXCESS ATTENUATION.
!  I            MAIN INDEX FOR LOOP TO CHECK RETURNED POWER UNTIL
!                POWER WAS LESS THAN MINIMUM DETECTABLE SIGNAL.
!  Ifreq        INDEX FOR INCREMENTS OF FREQUENCY
!  IND          INDEX USED FOR LOOP FOR DIFFERENT TRANSMITTED POWER
!  Interval     MAXIMUM EFFECTIVE-SCATTERING VOLUME THICKNESS.
!  Inver        HEIGHT OF INVERSION LAYER.
!  J            FIRST ORDER INDEX FOR ASSORTED LOOPS.
!  K            WAVENUMBER
!  L            SECOND ORDER INDEX FOR ASSORTED LOOPS.
!  Mess_up      TEST VALUE TO CHECK RESPONSES WHEN OPERATOR IS INPUTTING
!                RESPONSES.
!  N            TEST VALUE IN CALCULATION OF COHERENCE LENTH IN CALCULATION
!                OF EXCESS ATTENUATION.
!  New_va       TEST VALUE IN CHECKING IF OPERATOR WISHES TO CHANGE
!                A VARIABLE BEFORE A NEW RUN.
!  Noise        ASSUMED MINIMUM DETECTABLE SIGNAL.
!  Pow_back(*) POWER BACKSCATTERED FROM GIVEN RANGE.
!  Pow_ret(*)  POWER BACKSCATTERED TO ECHOSOUNDER FROM GIVEN RANGE.
!  Pow_trans    INPUT OF POWER SUPPLIED TO TRANSDUCER OF ECHOSOUNDER.
!  Profile      OPERATOR INPUT OF Cte2 PROFILE FROM AVAILABLE PROFILES.
!  Pstar        VARIABLE USED IN SUBPROGRAM ATTENUATION FOR INTERMEDIATE
!                CALCULATION.
!  Pulse        TRANSMITTED PULSE LENGTH IN MILLISECONDS.  INPUT BY
!                OPERATOR.
!  R            RANGE FOR INPUT TO INTEGRAL OF EXCESS ATTENUATION.
!  R1           VARIABLE USED IN SCALING INVERSION HEIGHT FOR PROFILE THREE.
!  Range(*)     ARRAY OF RANGE VALUES.
```

```
!  Remainder  REMAINDER OF MODULO FUNCTION USED TO DECREES THE
!              NUMBER OF PASSES THROUGH THE INTEGRATION FOR EXCESS
!              ATTENUATION.
!  Rge        VALUE OF RANGE IN INTEGRAL FOR EXCESS ATTENUATION.
!  Rho        CORRELATION LENGTH USED IN CALCULATION OF EXCESS
!              ATTENUATION.
!  Sigma      FRACTION OF ENERGY BACKSCATTERED FROM GIVEN RANGE.
!  Speed_sound SPEED OF SOUND IN AIR AT INPUT TEMPERATURE.
!  Sumpow_back
!  T          INPUT TEMPERATURE IN DEGREES KELVIN.
!  Temp       INPUT TEMPERATURE IN DEGREES CELSIUS.
!  Temp$      VARIABLE STRING USED IN FUNCTION YES.
!
!  Tstar      INTERMEDIATE VALUE USED IN CALCULATION OF ATTENUATION
!              IN SUBPROGRAM ATTENUATION.
!  Var        USED TO SELECT THE VARIABLE THE OPERATOR WISHED TO
!              CHANGE BEFORE MAKING ANOTHER RUN.
!  Wat_pres   ATMOSPHERIC WATER PRESSURE IN MILLIBARS.  INPUT BY
!              OPERATOR.
!  X          THIRD ORDER INDEX USED IN VARIOUS LOOPS.
!  X$         STRING PASSED TO FUNCTION YES TO DETERMINE OPERATOR
!              RESPONSE TO YES OR NO QUESTION.
!  Xmax       VALUE OF LARGEST VALUE OF X FOR VARIOUS PLOTS.
!  Xmin       VALUE OF SMALLEST VALUE OF X FOR VARIOUS PLOTS.
!  Xrange     VALUE OF RANGE OF X VALUES FOR VARIOUS PLOTS.
!  Ylabel$    LABEL ON Y AXIS PASSED TO SUBPROGRAM Semi_log FOR PLOTTING.
!  Ymax       LARGEST VALUE OF Y VARIABLE FOR VARIOUS PLOTS.
!  Ymin       SMALLEST VALUE OF Y VARIABLE FOR VARIOUS PLOTS.
!  Yrange     RANGE OF Y VARIABLES FOR VARIOUS PLOTS.
!  Ze         INTERMEDIATE VALUE IN CALCULATION OF EXCESS ATTENUATION.
!
!
!DECLARE VARIABLES
INTEGER I
DIM Pow_back(1500),Pow_ret(1500),Range(1500)
DIM Cne2(1500),Ran(50,6)
!
PLOTTER IS 705,"HPGL"
LINE TYPE 1
!
!INPUT ATMOSPHERIC DATA
INPUT "ENTER TEMPERATURE IN DEGREES CELCIUS",Temp
INPUT "ENTER ATMOSPHERIC PRESSURE IN MILLIBARS",Atom_pres
INPUT "ENTER WATER VAPOR PRESSURE IN MILLIBARS",Wat_pres
!
!
!INPUT ECHOSOUNDER DATA
INPUT "ENTER ECHOSOUNDER PULSE LENGTH IN MILLISECONDS=",Pulse
INPUT "ENTER THE ECHOSOUNDER ANTENNA DIAMETER IN METERS",Ant_diam
G=.40          !ANTENNA EFFECTIVE APERATURE FACTOR
```

```
Eff=.25
!
!
!SELECT THE PROFILE FOR THE TEMPERATURE STRUCTURE
PRINT "YOU HAVE A CHOICE OF TEMPERATURE STRUCTURE PROFILES"
PRINT "PROFILE TO BE USED."
PRINT "YOUR SELECTIONS ARE"
PRINT "     1      A TEMPERARURE STRUCTURE PROFILE BASED ON DATA AS "
PRINT "            PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398 WHICH "
PRINT "             GIVES A HEIGHT TO THE -1.16 PROFILE"
PRINT " "
PRINT "     2      THE TEMPERATURE STRUCTURE PROFILE ABOVE BUT"
PRINT "            WITH A FACTOR OF TWO TO APPROXIMATE LOOKING"
PRINT "            UP A THERMAL PLOOM"
PRINT " "
PRINT "     3      A TEMPERATURE STRUCTURE PROFILE BASED ON DATA AS"
PRINT "            PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398 FOR"
PRINT "            NIGHT CONDITIONS.  THE DEPENDENCE WITH HEIGHT "
PRINT "            IS EXP(-.001*HEIGHT ABOVE 65 METERS AND HEIGHT"
PRINT "            TO THE -1.46 BELOW 65 METERS"
PRINT " "
PRINT "     4      A TEMPERATURE STRUCTURE PROFILE BASED ON A"
PRINT "             HEIGHT TO THE -4/3 "
!
PRINT " "
PRINT " "
Mess_up=1
WHILE Mess_up=1
     INPUT "ENTER THE DESIRED PROFILE (1 OR 2 OR 3 OR 4)",Profile
     IF Profile=4 THEN
          INPUT "ENTER THE HEIGHT OF THE INVERSION IN METERS",Inver
     END IF
     IF Profile=1 THEN
         Mess_up=0
     ELSE
         IF Profile=2 THEN
              Mess_up=0
         ELSE
              IF Profile=3 THEN
                   Mess_up=0
              ELSE
                   IF Profile=4 THEN
                        Mess_up=0
                   ELSE
                        PRINT Profile," WAS NOT ONE OF THE OPTIONS!!!!"
                        Mess_up=1
                   END IF
              END IF
         END IF
      END IF
```

```
END WHILE
OUTPUT KBD;"K";
!
!
Again=1
WHILE Again=1
  FOR J=1 TO I
     Pow_back(J)=0
     Pow_ret(J)=0
     Range(J)=0
     Cne2(J)=0
  NEXT J
  !
  !CONVERT TEMPERATURE TO KELVIN
  T=Temp+273
  !
  !CALCULATE SPEED OF SOUND BASED ON INPUT TEMPERATURE(CELCIUS)
  Speed_sound=20.05*(T)^.5
  !CALCULATE THE SPEED OF SOUND AT 0 DEGREES CELCIUS
  C=20.05*273^.5
  !
  I=1     !INDEX FOR INNER LOOP (POWER RETURNED TO NOISE)
  Ind=1  !INDEX FOR SECOND LOOP (EFFICIENCY)
  Ifreq=1 !INDEX FOR THIRD LOOP (FREQUENCY)
  Pow_back(0)=0     !INITIALIZE VARIABLE FOR POWER BACKSCATERRED
  Interval=(Speed_sound*Pulse*1.E-3)/2
  Ant_area=PI*(Ant_diam/2)^2
  !
  !INITIALIZE PLOTTING PARAMETERS SO CAN COMPARE DURING RUN TO SCALE
  !PLOTS
  Ymin=1000
  Ymax=0
  !CALCULATE RETURNED SIGNAL POWER UNTIL IT IS LESS THAN BACKGROUND
  !FOR EACH FREQUENCY.
  Range(0)=0
  FOR Freq=500 TO 1500 STEP 500
   FOR Pow_trans=50 TO 500 STEP 50
    Bn=2*Freq*(1-1/(6/Speed_sound+1))!BANDWIDTH FOR 3M/S VERTICAL VELOCITY
    Noise=1.38E-23*Bn*(T)+2.E-14!MINIMUM DETECTABLE SIGNAL AS
    !      JOHNSON NOISE(NEGLIGABLE)+ ESTIMATED BACKGROUND
    !CALCULATE THE ATTENUATION COEFFICIENT BASED ON ATMOSPHERIC DATA
    CALL Attenuation(Atom_pres,Atten,Freq,Temp,Wat_pres)
    K=2*PI*Freq/Speed_sound    !WAVENUMBER
    I=1
    Sumpow_back=0
    REPEAT
     Range(I)=Range(I-1)+2
     SELECT Profile
           CASE 1
           !THIS TEMPERATURE STRUCTURE PROFILE IS BASED UPON DATA
```

```
    !AS PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398.
    !WAS FOR MIDDAY AND CLEAR WEATHER ABOVE THE
    !TULAROSA BASIN, NEW MEXICO.
    !AN ADDITONAL FACTOR OF 1.8 WAS INCLUDED AS PER DIFFERENT
    !AVERAGING TIME.
        Cte2=2.12*Range(I)^(-1.16)
    CASE 2
    !THIS TEMPERATURE STRUCTURE PROFILE IS BASED UPON DATA
    !AS PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398.
    !WAS FOR MIDDAY AND CLEAR WEATHER ABOVE THE
    !TULAROSA BASIN, NEW MEXICO.
    !AN ADDITONAL FACTOR OF 1.8 WAS INCLUDED AS PER DIFFERENT
    !AVERAGING TIME AND AN ADDITIONAL FACTOR OF TWO WAS
    !INCLUDED TO APPROXIMATE LOOKING UP A THERMAL PLOOM
        Cte2=2*2.12*Range(I)^(-1.16)
    CASE 3
    !THIS TEMPERATURE STRUCTURE PROFILE BASED ON DATA AS"
    !PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398 FOR"
    !NIGHT CONDITIONS.  THE DEPENDENCE WITH HEIGHT "
    !IS EXP(-.001*HEIGHT ABOVE 65 METERS AND HEIGHT"
    !TO THE -1.46 BELOW 65 METERS"
        IF Range(I)<65 THEN
             Cte2=75.5*Range(I)^(-1.46)
        ELSE
             Cte2=3.66E-2*EXP(-.001*Range(I))
        END IF
    CASE 4
    !CALCULATE THE TEMPERATURE STRUCTURE FACTOR BASED ON ASSUMPTION
    !    THAT IT'S PROPORTIONAL TO HEIGHT TO THE -4/3 POWER
    !    THAT THE SURFACE VERTICAL HEAT FLUX IS .095 C.m./sec
    !THE DEPENDENCE WITH HEIGHT ABOVE THE INVERSION I PULLED FROM
    !MY LEFT EAR
    !EQUATION FROM NEFF, 1975
    SELECT Range(I)/Inver
         CASE <.9
              C3=(( 024)*(T)^(.667))
              Cte2=C3*(Range(I))^(-1.33)
         CASE .9 TO 1
              Cte2=Cte2
              C1=Cte2
              R1=Range(I)
         CASE 1 TO 1.3
              Cte2=10^((LGT(C3*Range(I))-LGT(C3*R1))+LGT(C1))
              R2=Range(I)
              C2=Cte2
         CASE ELSE
              Cte2=C3*(Range(I)^(-1.33)-R2^(-1.33))+C2
    END SELECT
END SELECT
!CALCULATE VELOCITY STRUCTURE FACTOR. FORMULA FROM GAYNOR 77
```

```
Epsilon=(.2866/Range(I))*(1+.07*(Range(I))^(.6))^(1.5)
Cve2=2*Epsilon^(.667)
!CALCULATE ACOUSTIC REFRACTIVE INDEX STRUCTURE FACTOR,
!FORMULA FROM TETARSKI
Cne2(I)=(Cte2/(2.98E+5))+(Cve2/(C*C))
!CALCULATE THE FRACTION OF POWER BACKSCATTERED FROM INTERVAL.
!EQUATION FROM NEFF, 1975
Sigma=(.0039*(K^(1/3))*Cte2)/(T)^2
!
!CALCULATE THE EXCESS ATTENUATION.  EQUATION FROM CLIFFORD, 1980
!THE EXCESS ATTENUATION IS Exc_att
IF I<50 THEN
    Remainder=0
ELSE
    IF I<150 THEN
         Remainder=Range(I) MODULO 10
    ELSE
         Remainder=Range(I) MODULO 20
    END IF
END IF
IF Remainder=0 THEN
    Rho=0
    L=0
    H=0
    Rge=Range(I)    !CONSTANT IN INTEGRAL
    R=0
    FOR J=0 TO 2*I
              F=Cne2(INT(J/2+1))
              F=F*(1-R/(Rge)^(1.67)+(R/(Rge))^(1.67))
              IF J>0 THEN
                  IF J<2*I THEN
                      IF INT(J/2)=J/2 THEN
                          L=L+F
                          F=0
                      ELSE
                          H=H+F
                          F=0
                      END IF
                  END IF
              END IF
              Rho=Rho+F
              R=R+1
    NEXT J
    Rho=Rho+4*L+2*H
    Rho=(((Rho*.33)*K*K*1.46)^(-.6))
    N=(Ant_diam/Rho)^2
    IF N<=1 THEN
         Ze=1/(1+N)
    ELSE
         Ze=1.5/(1+N)
```

```
                 !STEP OF 1.5==>SEE CLIFFORD 1980
            END IF
            Exc_att=Ze*Ze
        ELSE
            Exc_att=Exc_att
        END IF
        !
        !CALCULATE THE POWER BACKSCATTERED
        Pow_back(I)=(Pow_trans*Eff-Sumpow_back)*EXP(-Atten*Range(I))
        Pow_back(I)=Pow_back(I)*Interval*Exc_att*Sigma
        Sumpow_back=Sumpow_back+Pow_back(I)
        !CALCULATE THE POWER BACKSCATTERED TO THE ANTENNA
      Pow_ret(I)=Pow_back(I)*EXP(-Atten*Range(I))*Ant_area*G*Eff/Range(I)^2
        PRINT "RANGE=",Range(I)
        PRINT "POWER RETURNED=",Pow_ret(I)
        PRINT "FREQUENCY=",Freq
        I=I+1
     UNTIL Pow_ret(I-1)>0 AND Pow_ret(I-1)<=Noise
     Ran(Ind,Ifreq)=Range(I-2)
     IF Ran(Ind,Ifreq)>Ymax THEN
         Ymax=Ran(Ind,Ifreq)
     END IF
     IF Ran(Ind,Ifreq)<Ymin THEN
         Ymin=Ran(Ind,Ifreq)
     END IF
     Ind=Ind+1
     Again=1
     FOR J=0 TO I
        Pow_back(J)=0
        Pow_ret(J)=0
        Range(J)=0
        Cne2(J)=0
     NEXT J
    NEXT Pow_trans
    Ifreq=Ifreq+1
    Ind=1
  NEXT Freq
  !
  !
  OUTPUT KBD;"K";
  PRINT "INPUT CONDITIONS"
  !
  PRINT " "
  PRINT USING "K";"TEMPERATURE=                ",Temp,"CELCIUS"
  PRINT USING "K";"ATMOSPHERIC PRESSURE=       ",Atom_pres,"mb"
  PRINT USING "K";"WATER VAPOR PRESSURE=       ",Wat_pres,"mb"
  PRINT USING "K";"PULSE LENGTH=               ",Pulse,"ms"
  PRINT USING "K";"TRANSDUCER EFFICIENCY=      ",Eff
  PRINT USING "K";"POWER TRANSMITTED=          ",Pow_trans," WATTS"
  PRINT "TEMPERATURE STRUCTURE PROFILE USED ",Profile
```

```
IF Profile=4 THEN
   PRINT "INVERSION HEIGHT ",Inver
END IF
SELECT Profile
   CASE 1
       PRINT "     1      A TEMPERARURE STRUCTURE PROFILE BASED ON DATA"
       PRINT "            AS PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398 "
       PRINT "            WHICH GIVES A HEIGHT TO THE -1.16 PROFILE"
   CASE 2
       PRINT "     2      A TEMPERARURE STRUCTURE PROFILE BASED ON DATA"
       PRINT "            AS PRESENTED IN WA_TERS/KUNDEL 1981 PAGE 398 "
       PRINT "            WHICH GIVES A HEIGHT TO THE -1.16 PROFILE"
       PRINT "            BUT WITH A FACTOR OF TWO TO APPROXIMATE"
       PRINT "            LOOKING UP A THERMAL PLOOM"
   CASE 3
       PRINT "     3      A TEMPERATURE STRUCTURE PROFILE BASED ON DATA"
       PRINT "            AS PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398"
       PRINT "            FOR NIGHT CONDITIONS.  THE DEPENDENCE WITH"
       PRINT "            HEIGHT IS EXP(-.001*HEIGHT ABOVE 65 METERS"
       PRINT "            AND HEIGHT TO THE -1.46 BELOW 65 METERS"
   CASE 4
       PRINT "     4      A TEMPERATURE STRUCTURE PROFILE BASED ON A"
       PRINT "             HEIGHT TO THE -4/3 "
END SELECT
!
PRINT USING "K";"THE MINIMUM DETECTABLE SIGNAL WAS SET AT",Noise,"WATTS"
!
PRINT " "
!
!
PRINT "HIT CONTINUE TO CONTINUE"
PAUSE
OUTPUT KBD;"K";
!
GRAPHICS ON
VIEWPORT 15,120,10,70
!
!
!PLOT RANGE VERSUS POWER TRANSMITTED FOR VARIOUS FREQUENCIES
Xmin=0
Xmax=600
Ymin=PROUND(Ymin-50,2)
Ymax=PROUND(Ymax+50,2)
Dx=100
Dy=100
Xrange=Xmax-Xmin
Yrange=Ymax-Ymin
WINDOW Xmin,Xmax,Ymin,Ymax
AXES Dx,Dy,Xmin,Ymin,1,1
CLIP OFF
```

```
!
!LABEL PLOT
CSIZE 4,.6
LDIR 0
LORG 5
MOVE .5*Xrange,Ymax*1.05
LABEL "RANGE VERSUS POWER TRANSMITTED"
!LABEL HORIZONTAL AXES
LDIR 0
LORG 5
FOR J=0 TO Xmax STEP Dx
   CSIZE 4,.6
   MOVE J,Ymin-.05*Yrange
   LABEL J
NEXT J
MOVE .5*Xrange,Ymin-.1*Yrange
CSIZE 4,.6
LABEL "POWER TRANSMITTED (WATTS)"
!LABEL VERTICAL AXES
LORG 8
FOR J=Ymin TO Ymax STEP Dy
   CSIZE 4,.6
   MOVE Xmin-.0025*Xrange,J
   LABEL USING "K";J
NEXT J
LDIR PI/2
LORG 6
MOVE Xmin-.15*Xrange,.5*Yrange+Ymin
CSIZE 4,.6
LABEL "RANGE (METERS)"
CLIP ON
Ind=1
Ifreq=1
FOR Freq=500 TO 1500 STEP 500
  FOR Pow_trans=50 TO 500 STEP 50
     IF INT(Ifreq/2)=Ifreq/2 THEN
        LINE TYPE 3
     ELSE
        LINE TYPE 1
     END IF
     PLOT Pow_trans,Ran(Ind,Ifreq)
     Ind=Ind+1
  NEXT Pow_trans
  LDIR 0
  LORG 2
  CSIZE 3,.6
  MOVE Pow_trans-50,Ran(Ind-1,Ifreq)
  LINE TYPE 1
  LABEL USING "K";Freq,"Hz"
  Ifreq=Ifreq+1
```

```
  Ind=1
NEXT Freq
!
PRINT "HIT CONTINUE TO CONTINUE"
PAUSE
GCLEAR
OUTPUT KBD;"K";
!
!
LINPUT "WOULD YOU LIKE TO MAKE ANOTHER RUN (ENTER Y OR N)?",X$
Again=FNYes(X$)
Mess_up=1
WHILE Mess_up=1
 SELECT Again
   CASE 1
       LINPUT "WOULD YOU LIKE TO CHANGE A VARIABLE (ENTER Y OR N)?",X$
        New_va=FNYes(X$)
        Ano_change=1
        WHILE Ano_change=1
          SELECT New_va
             CASE 1
              PRINT "       VARIABLE           CURRENT VALUE"
              PRINT USING "K";"1  TEMPERATURE         ",Temp,"CELSIUS"
              PRINT USING "K";"2  ATOMOSPHERIC PRESSURE ",Atom_pres,"mb"
              PRINT USING "K";"3  WATER VAPOR PRESSURE ",Wat_pres,"mb"
              PRINT " "
              PRINT USING "K";"4  ANTENNA DIAMETER     ",Ant_diam," m."
              PRINT USING "K";"5  PULSE LENGTH         ",Pulse," ms"
              PRINT USING "K";"6  POWER TRANSMITTED ",Pow_trans," WATTS"
              PRINT USING "K";"7  ATMOSPHERIC PROFILE  ",Profile
              PRINT " "
              PRINT "ENTER THE NUMBER OF THE VARIABLE YOU WISH TO"
              PRINT "CHANGE"
              INPUT Var
              SELECT Var
                       CASE 1
                          INPUT "TEMPERATURE=",Temp
                       CASE 2
                          INPUT "ATMOSPHERIC PRESSURE IN mb=",Atom_pres
                       CASE 3
                          INPUT "WATER VAPOR PRESSURE IN mb=",Wat_pres
                       CASE 4
                          INPUT "ANTENNA DIAMETER IN m.=",Ant_diam
                       CASE 5
                          INPUT "PULSE LENGTH IN ms=",Pulse
                       CASE 6
                          INPUT "POWER TRANSMITTED IN WATTS=",Pow_trans
                       CASE 7
                         PRINT " 1  ==> Ct^2 PROFILE OF Z^(-1.16)"
                         PRINT "        FROM WALTERS/KUNDEL 1981"
```

```
                            PRINT " 2  ==> SAME AS ONE BUT WITH FACTOR"
                            PRINT "        OF TWO TO APPROXIMATE LOOKING"
                            PRINT "        UP A THERMAL PLOOM"
                            PRINT " 3  ==> Ct^2 PROFILE OF EXP(-.001*Z)"
                            PRINT "        FROM WALTERS/KUNDEL 1981."
                            PRINT " 4  ==> CT^2 PROFILE OF Z^(-4/3)"
                            INPUT "ENTER NUMBER OF DESIRED PROFILE",Profile
                            IF Profile=4 THEN
                             INPUT "HEIGHT OF INVERSION IN METERS=",Inver
                            END IF
                          CASE ELSE
                            PRINT Var,"IS NOT ONE OF THE OPTIONS"
                     END SELECT
                     LINPUT "MADE ANOTHER CHANGE(ENTER Y OR N)?",X$
                     New_va=FNYes(X$)
                     Mess_up=2
                CASE 2
                     Mess_up=2
                     Ano_change=2
                CASE ELSE
                     PRINT "YOUR CHOICES WHERE Y OR N !!!!!"
                     Ano_change=1
                     LINPUT "CHANGE A VARIABLE (ENTER Y OR N)?",X$
                     New_va=FNYes(X$)
            END SELECT
          END WHILE
      CASE 2
          Mess_up=2
      CASE ELSE
          PRINT "YOUR CHOICES WHERE Y OR N  !!!!!!"
          Mess_up=1
          LINPUT "MAKE ANOTHER RUN (ENTER Y OR N)?",X$
          Again=FNYes(X$)
    END SELECT
  END WHILE
END WHILE
PRINT "THAT'S ALL, FOLKS"
end
!
!
!CALCULTE THE ATTENUATION
sub Attenuation(Atom_pres,Atten,Freq,Temp,Wat_pres)
!THIS SUBPROGRAM CALCULATES THE ATTENUATION OF SOUND
!IN AIR BASED UPON EQUATIONS IN NEFF 1975
!
!   INPUT   ATMOSPHERIC PRESSURE IN MILLIBARS
!           FREQUENCY OF SOUND WAVE IN HERTZ
!           TEMPERATURE IN DEGREES CELCIUS
!           WATER-VAPOR PRESSURE IN MILLIBARS
!
```

```
!   OUTPUT  ATTENUATION IN 1/METERS
!
!VARIABLES
!  Atom_pres  INPUT OF ATMOSPHERIC PRESSURE IN mb.
!  Atten      ATTENUATION OF ACOUSTIC WAVE.  CALCULATED IN
!              SUBPROGRAM ATTENUATION.
!  Att_max    VARIABLE IN SUBPROGRAM ATTENUATION.  IT IS THE
!              ATTENUATION AT THE FREQUENCY OF THE MAXIMUM
!              ATTENUATION FOR THE INPUT CONDITIONS.
!  F          VARIABLE USED IN SUBPROGRAM ATTENUATION.  IS THE
!              RATIO OF FREQUENCY TO FREQUENCY AT MAXIMUM ATTENUATION.
!  Fmax       FREQUENCY OF MAXIMUM ATTENUATION. USED IN SUBPROGRAM
!              ATTENUATION.
!  Freq       INPUT FREQUENCY OF ECHOSOUNDER.
!  H          VARIABLE USED IN INTEGRATION FOR EXCESS ATTENUATION.
!  Pstar      VARIABLE USED IN SUBPROGRAM ATTENUATION FOR INTERMEDIATE
!              CALCULATION.
!  Temp       INPUT TEMPERATURE IN DEGREES CELSIUS.
!  Tstar      INTERMEDIATE VALUE USED IN CALCULATION OF ATTENUATION
!              IN SUBPROGRAM ATTENUATION.
!  Wat_pres   ATMOSPHERIC WATER PRESSURE IN MILLIBARS.  INPUT BY
!              OPERATOR.
H=100*Wat_pres/Atom_pres
Tstar=(1.8*Temp+492)/519
Pstar=Atom_pres/1014
Fmax=(10+6600*H+44400*H*H)*Pstar/Tstar^.8
Att_max=.0078*Fmax*Tstar^(-2.5)*EXP(7.77*(1-1/Tstar))
F=Freq/Fmax
Atten=(Att_max/304.8)*((.18*F)^2+(2*F*F/(1+F*F))^2)^.5
Atten=(Atten+1.74E-10*Freq*Freq)/4.35
SUBEND
!
def FNYes(X$)
!THIS FUNCTION INTERPRETS THE OPERATORS RESPONSES TO YES NO QUESTIONS
!
!    INPUT     X$
!
!    OUTPUT    FNYes
!VARIABLES
!  Temp$      VARIABLE STRING USED IN FUNCTION YES.
!  X$         STRING PASSED TO FUNCTION YES TO DETERMINE OPERATOR
!              RESPONSE TO YES OR NO QUESTION.
     DIM Temp$[1]
     Temp$[1,1]=TRIM$(X$)
     SELECT Temp$
     CASE "Y","y"
          RETURN 1
     CASE "N","n"
          RETURN 2
     CASE " "
```

```
          RETURN 1
     CASE ELSE
          RETURN -2
     END SELECT
FNEND
!
```

APPENDIX F

COMPUTER PROGRAM 6

```
!FULLER, ROBERT       PROG_6       NOISE
!
!10 SEP 85
!
!
!*******PURPOSE*******
!
!     THIS PROGRAM WILL TAKE PARAMETERS OF AN ECHOSOUNDER AND
!ESTIMATE THE RANGE AS A FUNCTION OF BACKGROUND NOISE
!THE FOLLOWING INPUTS ARE REQUIRED:
!    ATMOSPHERIC DATA
!    1)ATOMOSPHERIC PRESSURE in millibars
!    2)SELECT ONE OF FOUR ATMOSPHERIC PROFILES FOR THE TEMPERATURE
!      STRUCTURE PROFILE.
!       a)FOR ONE PROFILE THE HEIGHT OF THE INVERSION LAYER IS ALSO INPUT
!    3)TEMPERATURE IN DEGREES CELSIUS
!    4)WATER VAPOR PRESSURE IN millibars
!
!    ECHOSOUNDER DATA
!    5)FREQUENCY
!    6)ANTENNA DIAMETER IN METERS
!    7)PULSE LENGTH OF THE TRANSMITTED ACOUSTIC ENERGY
!    8)POWER TRANSMITTED
!
!THE PROGRAM OUTPUTS THE FOLLOWING GRAPH TO AN EXTERNAL PLOTTER:
!    1)RANGE(m.) VERSUS BACKGROUND NOISE IN WATTS
!
!
!*****VARIABLES*****
!
!
!  Again      TEST VALUE IN WHILE LOOP TO DETERMINE IF OPERATOR
!              WISHES TO MAKE ANOUTHER RUN.
!  Ano_change TEST VALUE IN WHILE LOOP TO DETERMINE IF OPERATOR
!              WISHES TO CHANGE THE VALUE OF INPUT DATA BEFORE MAKING
!              ANOUTHER RUN.
!  Ant_area   ECHOSOUNDER ANTENNA AREA CALCULATED FROM INPUT OF
!              ANTENNA DIAMETER.
!  Ant_diam   INPUT OF ECHOSOUNDER ANTENNA DIAMETER IN METERS.
!  Atom_pres  INPUT OF ATMOSPHERIC PRESSURE IN mb.
!  Atten      ATTENUATION OF ACOUSTIC WAVE.  CALCULATED IN
!              SUBPROGRAM ATTENUATION.
!  C          VELOCITY OF SOUND CALCULATION AT ZERO CELSIUS.
!  C1         VARIABLE USED TO SCALE INVERSION HEIGHT IN
!              TEMPERATURE STRUCTURE PROFILE THREE.
!  C3         VARIABLE USED IN CALCULATING THE FOURTH Cte2 PROFILE.
!  Cne2(*)    ARRAY OF VALUES OF THE ACOUSTIC REFRACTIVE INDEX
!              PARAMETER.  CALCULATED BASED ON SELECTION OF
!              PROFILE FOR TEMPERATURE STRUCTURE PARAMETER
!              AND ASSUMED PROFILE FOR THE VELOCITY STRUCTURE
```

```
!                 PARAMETER.
! Cte2          VALUE OF THE TEMPERATURE STRUCTURE PARAMETER.
!                 THE OPERATOR SELECTS A PROFILE FROM SEVERAL PROVIDED.
! Cve2          VALUE OF THE VELOCITY STRUCTURE  PARAMETER.
!                 VALUES BASED ON CALCULATION USING ASSUMED DISSAPATION
!                 RATE.
! Dx            STEP SIZE FOR X AXIS FOR VARIOUS PLOTS.
! Dy            STEP SIZE FOR Y AXIS FOR VARIOUS PLOTS.
! Epsilon       DISSAPATION RATE USED IN CALCULATION OF Cve2.
! Eff           TRANSMISSION EFFICIENCY OF ECHOSOUNDER.
! Eff           EFFICIENCY OF ECHOSOUNDER WHEN RECEIVING ACOUSTIC
!                 BACKSCATTER.
! Exc_att       EXCESS "ATTENUATION" AT GIVEN RANGE.
! F             VARIABLE USED IN SUBPROGRAM ATTENUATION.  IS THE
!                 RATIO OF FREQUENCY TO FREQUENCY AT MAXIMUM ATTENUATION.
! Fmax          FREQUENCY OF MAXIMUM ATTENUATION. USED IN SUBPROGRAM
!                 ATTENUATION.
! Freq          INPUT FREQUENCY OF ECHOSOUNDER.
! G             ANTENNA EFFECTIVE APERATURE FACTOR.
! H             VARIABLE USED IN INTEGRATION FOR EXCESS ATTENUATION.
! I             MAIN INDEX FOR LOOP TO CHECK RETURNED POWER UNTIL
!                 POWER WAS LESS THAN MINIMUM DETECTABLE SIGNAL.
! IND           INDEX USED FOR LOOP FOR DIFFERENT NOISE CUT OFF LEVELS
! Interval      MAXIMUM EFFECTIVE-SCATTERING VOLUME THICKNESS.
! Inver         HEIGHT OF INVERSION LAYER.
! J             FIRST ORDER INDEX FOR ASSORTED LOOPS.
! K             WAVENUMBER
! L             SECOND ORDER INDEX FOR ASSORTED LOOPS.
! Mess_up       TEST VALUE TO CHECK RESPONSES WHEN OPERATOR IS INPUTTING
!                 RESPONSES.
! N             TEST VALUE IN CALCULATION OF COHERENCE LENTH IN CALCULATION
!                 OF EXCESS ATTENUATION.
! New_va        TEST VALUE IN CHECKING IF OPERATOR WISHES TO CHANGE
!                 A VARIABLE BEFORE A NEW RUN.
! Noise         ASSUMED MINIMUM DETECTABLE SIGNAL.
! Pow_back(*) POWER BACKSCATTERED FROM GIVEN RANGE.
! Pow_ret(*)  POWER BACKSCATTERED TO ECHOSOUNDER FROM GIVEN RANGE.
! Pow_trans     INPUT OF POWER SUPPLIED TO TRANSDUCER OF ECHOSOUNDER.
! Profile       OPERATOR INPUT OF Cte2 PROFILE FROM AVAILABLE PROFILES.
! Pstar         VARIABLE USED IN SUBPROGRAM ATTENUATION FOR INTERMEDIATE
!                 CALCULATION.
! Pulse         TRANSMITTED PULSE LENGTH IN MILLISECONDS.  INPUT BY
!                 OPERATOR.
! R             RANGE FOR INPUT TO INTEGRAL OF EXCESS ATTENUATION.
! R1            VARIABLE USED IN SCALING INVERSION HEIGHT FOR PROFILE THREE.
! Range(*)      ARRAY OF RANGE VALUES.
! Remainder     REMAINDER OF MODULO FUNCTION USED TO DECREES THE
!                 NUMBER OF PASSES THROUGH THE INTEGRATION FOR EXCESS
!                 ATTENUATION.
! Rge           VALUE OF RANGE IN INTEGRAL FOR EXCESS ATTENUATION.
```

```
!  Rho         CORRELATION LENGTH USED IN CALCULATION OF EXCESS
!               ATTENUATION.
!  Sigma       FRACTION OF ENERGY BACKSCATTERED FROM GIVEN RANGE.
!  Speed_sound SPEED OF SOUND IN AIR AT INPUT TEMPERATURE.
!  T           INPUT TEMPERATURE IN DEGREES KELVIN.
!  Temp        INPUT TEMPERATURE IN DEGREES CELSIUS.
!  Sumpow_back
!  Temp$       VARIABLE STRING USED IN FUNCTION YES.
!
!  Tstar       INTERMEDIATE VALUE USED IN CALCULATION OF ATTENUATION
!               IN SUBPROGRAM ATTENUATION.
!  Var         USED TO SELECT THE VARIABLE THE OPERATOR WISHED TO
!               CHANGE BEFORE MAKING ANOTHER RUN.
!  Wat_pres    ATMOSPHERIC WATER PRESSURE IN MILLIBARS.  INPUT BY
!               OPERATOR.
!  X           THIRD ORDER INDEX USED IN VARIOUS LOOPS.
!  X$          STRING PASSED TO FUNCTION YES TO DETERMINE OPERATOR
!               RESPONSE TO YES OR NO QUESTION.
!  Xmax        VALUE OF LARGEST VALUE OF X FOR VARIOUS PLOTS.
!  Xmin        VALUE OF SMALLEST VALUE OF X FOR VARIOUS PLOTS.
!  Xrange      VALUE OF RANGE OF X VALUES FOR VARIOUS PLOTS.
!  Ylabel$     LABEL ON Y AXIS PASSED TO SUBPROGRAM Semi_log FOR PLOTTING.
!  Ymax        LARGEST VALUE OF Y VARIABLE FOR VARIOUS PLOTS.
!  Ymin        SMALLEST VALUE OF Y VARIABLE FOR VARIOUS PLOTS.
!  Yrange      RANGE OF Y VARIABLES FOR VARIOUS PLOTS.
!  Ze          INTERMEDIATE VALUE IN CALCULATION OF EXCESS ATTENUATION.
!
!
!DECLARE VARIABLES
INTEGER I
DIM Pow_back(5000),Pow_ret(5000),Range(5000)
DIM Cne2(5000),Ran(50)
!
PLOTTER IS 705,"HPGL"
LINE TYPE 1
!
!INPUT ATMOSPHERIC DATA
INPUT "ENTER TEMPERATURE IN DEGREES CELCIUS",Temp
INPUT "ENTER ATMOSPHERIC PRESSURE IN MILLIBARS",Atom_pres
INPUT "ENTER WATER VAPOR PRESSURE IN MILLIBARS",Wat_pres
!
!
!INPUT ECHOSOUNDER DATA
INPUT "ENTER ECHOSOUNDER FREQUENCY IN HERTZ",Freq
INPUT "ENTER ECHOSOUNDER PULSE LENGTH IN MILLISECONDS=",Pulse
INPUT "ENTER THE ECHOSOUNDER ANTENNA DIAMETER IN METERS",Ant_diam
INPUT "ENTER THE POWER TRANSMITTED IN WATTS",Pow_trans
G=.40          !ANTENNA EFFECTIVE APERATURE FACTOR
Eff=.25
!
```

```
!
!SELECT THE PROFILE FOR THE TEMPERATURE STRUCTURE
PRINT "YOU HAVE A CHOICE OF TEMPERATURE STRUCTURE PROFILES"
PRINT "PROFILE TO BE USED."
PRINT "YOUR SELECTIONS ARE"
PRINT "     1      A TEMPERARURE STRUCTURE PROFILE BASED ON DATA AS "
PRINT "            PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398 WHICH "
PRINT "             GIVES A HEIGHT TO THE -1.16 PROFILE"
PRINT " "
PRINT "     2      THE TEMPERATURE STRUCTURE PROFILE ABOVE BUT"
PRINT "            WITH A FACTOR OF TWO TO APPROXIMATE LOOKING"
PRINT "            UP A THERMAL PLOOM"
PRINT " "
PRINT "     3      A TEMPERATURE STRUCTURE PROFILE BASED ON DATA AS"
PRINT "            PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398 FOR"
PRINT "            NIGHT CONDITIONS.  THE DEPENDENCE WITH HEIGHT "
PRINT "            IS EXP(-.001*HEIGHT ABOVE 65 METERS AND HEIGHT"
PRINT "            TO THE -1.46 BELOW 65 METERS"
PRINT " "
PRINT "     4      A TEMPERATURE STRUCTURE PROFILE BASED ON A"
PRINT "             HEIGHT TO THE -4/3 "
!
PRINT " "
PRINT " "
Mess_up=1
WHILE Mess_up=1
     INPUT "ENTER THE DESIRED PROFILE (1 OR 2 OR 3 OR 4)",Profile
     IF Profile=4 THEN
          INPUT "ENTER THE HEIGHT OF THE INVERSION IN METERS",Inver
     END IF
     IF Profile=1 THEN
         Mess_up=0
     ELSE
         IF Profile=2 THEN
              Mess_up=0
         ELSE
              IF Profile=3 THEN
                   Mess_up=0
              ELSE
                   IF Profile=4 THEN
                        Mess_up=0
                   ELSE
                        PRINT Profile," WAS NOT ONE OF THE OPTIONS!!!!"
                        Mess_up=1
                   END IF
              END IF
         END IF
      END IF
END WHILE
OUTPUT KBD;"K";
```

```
!
!
Again=1
WHILE Again=1
  FOR J=1 TO I
     Pow_back(J)=0
     Pow_ret(J)=0
     Range(J)=0
     CneZ(J)=0
  NEXT J
  !
  !CONVERT TEMPERATURE TO KELVIN
  T=Temp+273
  !
  !CALCULATE SPEED OF SOUND BASED ON INPUT TEMPERATURE(CELCIUS)
  Speed_sound=20.05*(T)^.5
  !CALCULATE THE SPEED OF SOUND AT 0 DEGREES CELCIUS
  C=20.05*273^.5
  !
  I=1     !INDEX FOR INNER LOOP (POWER RETURNED TO NOISE)
  Ind=1   !INDEX FOR SECOND LOOP (NOISE)
  Pow_back(0)=0    !INITIALIZE VARIABLE FOR POWER BACKSCATERRED
  Interval=(Speed_sound*Pulse*1.E-3)/2
  Ant_area=PI*(Ant_diam/2)^2
  !
  !CALCULATE RETURNED SIGNAL POWER UNTIL IT IS LESS THAN BACKGROUND
  !FOR EACH FREQUENCY.
  Range(0)=0
  Noise=1.E-18
  FOR Ind=1 TO 5
    CALL Attenuation(Atom_pres,Atten,Freq,Temp,Wat_pres)
    K=2*PI*Freq/Speed_sound     !WAVENUMBER
    I=1
    REPEAT
     Range(I)=Range(I-1)+2
     Sumpow_back=0
     SELECT Profile
           CASE 1
           !THIS TEMPERATURE STRUCTURE PROFILE IS BASED UPON DATA
           !AS PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398.
           !WAS FOR MIDDAY AND CLEAR WEATHER ABOVE THE
           !TULAROSA BASIN, NEW MEXICO.
           !AN ADDITONAL FACTOR OF 1.8 WAS INCLUDED AS PER DIFFERENT
           !AVERAGING TIME.
               Cte2=2.12*Range(I)^(-1.16)
           CASE 2
           !THIS TEMPERATURE STRUCTURE PROFILE IS BASED UPON DATA
           !AS PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398.
           !WAS FOR MIDDAY AND CLEAR WEATHER ABOVE THE
           !TULAROSA BASIN, NEW MEXICO.
```

```
        !AN ADDITONAL FACTOR OF 1.8 WAS INCLUDED AS PER DIFFERENT
        !AVERAGING TIME AND AN ADDITIONAL FACTOR OF TWO WAS
        !INCLUDED TO APPROXIMATE LOOKING UP A THERMAL PLOOM
            Cte2=2*2.12*Range(I)^(-1.16)
        CASE 3
        !THIS TEMPERATURE STRUCTURE PROFILE BASED ON DATA AS"
        !PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398 FOR"
        !NIGHT CONDITIONS.  THE DEPENDENCE WITH HEIGHT "
        !IS EXP(-.001*HEIGHT ABOVE 65 METERS AND HEIGHT"
        !TO THE -1.46 BELOW 65 METERS"
            IF Range(I)<65 THEN
                 Cte2=75.5*Range(I)^(-1.46)
            ELSE
                 Cte2=3.66E-2*EXP(-.001*Range(I))
            END IF
        CASE 4
        !CALCULATE THE TEMPERATURE STRUCTURE FACTOR BASED ON ASSUMPTION
        !    THAT IT'S PROPORTIONAL TO HEIGHT TO THE -4/3 POWER
        !    THAT THE SURFACE VERTICAL HEAT FLUX IS .095 C.m./sec
        !THE DEPENDENCE WITH HEIGHT ABOVE THE INVERSION I PULLED FROM
        !MY LEFT EAR
        !EQUATION FROM NEFF, 1975
        SELECT Range(I)/Inver
             CASE <.9
                 C3=((.024)*(T)^(.667))
                 Cte2=C3*(Range(I))^(-1.33)
             CASE .9 TO 1
                 Cte2=Cte2
                 C1=Cte2
                 R1=Range(I)
             CASE 1 TO 1.3
                 Cte2=10^((LGT(C3*Range(I))-LGT(C3*R1))+LGT(C1))
                 R2=Range(I)
                 C2=Cte2
             CASE ELSE
                 Cte2=C3*(Range(I)^(-1.33)-R2^(-1.33))+C2
        END SELECT
    END SELECT
    !CALCULATE VELOCITY STRUCTURE FACTOR. FORMULA FROM GAYNOR 77
    Epsilon=(.2866/Range(I))*(1+.07*(Range(I))^(.6))^(1.5)
    Cve2=2*Epsilon^(.667)
    !CALCULATE ACOUSTIC REFRACTIVE INDEX STRUCTURE FACTOR.
    !FORMULA FROM TETARSKI
    Cne2(I)=(Cte2/(2.98E+5))+(Cve2/(C*C))
    !CALCULATE THE FRACTION OF POWER BACKSCATTERED FROM INTERVAL.
    !EQUATION FROM NEFF, 1975
    Sigma=(.0039*(K^(1/3))*Cte2)/(T)^2
    !
    !CALCULATE THE EXCESS ATTENUATION.  EQUATION FROM CLIFFORD, 1980
    !THE EXCESS ATTENUATION IS Exc_att
```

```
IF I<50 THEN
    Remainder=0
ELSE
    IF I<150 THEN
        Remainder=Range(I) MODULO 10
    ELSE
        Remainder=Range(I) MODULO 20
    END IF
END IF
IF Remainder=0 THEN
    Rho=0
    L=0
    H=0
    Rge=Range(I)     !CONSTANT IN INTEGRAL
    R=0
    FOR J=0 TO 2*I
            F=Cne2(INT(J/2+1))
            F=F*(1-R/(Rge)^(1.67)+(R/(Rge))^(1.67))
            IF J>0 THEN
                IF J<2*I THEN
                    IF INT(J/2)=J/2 THEN
                        L=L+F
                        F=0
                    ELSE
                        H=H+F
                        F=0
                    END IF
                END IF
            END IF
            Rho=Rho+F
            R=R+1
    NEXT J
    Rho=Rho+4*L+2*H
    Rho=(((Rho*.33)*K*K*1.46)^(-.6))
    N=(Ant_diam/Rho)^2
    IF N<=1 THEN
        Ze=1/(1+N)
    ELSE
        Ze=1.5/(1+N)
        !STEP OF 1.5==>SEE CLIFFORD 1980
    END IF
    Exc_att=Ze*Ze
ELSE
    Exc_att=Exc_att
END IF
!
!CALCULATE THE POWER BACKSCATTERED
Pow_back(I)=(Pow_trans*Eff-Sumpow_back)*EXP(-Atten*Range(I))
Pow_back(I)=Pow_back(I)*Interval*Exc_att*Sigma
Sumpow_back=Sumpow_back+Pow_back(I)
```

```
      !CALCULATE THE POWER BACKSCATTERED TO THE ANTENNA
    Pow_ret(I)=Pow_back(I)*EXP(-Atten*Range(I))*Ant_area*G*Eff/Range(I)^2
      PRINT "RANGE=",Range(I)
      PRINT "POWER RETURNED=",Pow_ret(I)
      PRINT "NOISE=",Noise
      I=I+1
   UNTIL Pow_ret(I-1)>0 AND Pow_ret(I-1)<=Noise
   Ran(Ind)=Range(I-2)
   Again=1
   FOR J=0 TO I
      Pow_back(J)=0
      Pow_ret(J)=0
      Range(J)=0
      Cne2(J)=0
   NEXT J
   Noise=Noise*10
NEXT Ind
!
!
OUTPUT KBD;"K";
PRINT "INPUT CONDITIONS"
!
PRINT " "
PRINT USING "K";"TEMPERATURE=            ",Temp,"CELCIUS"
PRINT USING "K";"ATMOSPHERIC PRESSURE=   ",Atom_pres,"mb"
PRINT USING "K";"WATER VAPOR PRESSURE=   ",Wat_pres,"mb"
PRINT USING "K";"FREQUENCY=              ",Freq," Hz"
PRINT USING "K";"PULSE LENGTH=           ",Pulse,"ms"
PRINT USING "K";"TRANSDUCER EFFICIENCY=  ",Eff
PRINT USING "K";"POWER TRANSMITTED=      ",Pow_trans," WATTS"
PRINT "TEMPERATURE STRUCTURE PROFILE USED ",Profile
IF Profile=4 THEN
   PRINT "INVERSION HEIGHT ",Inver
END IF
SELECT Profile
   CASE 1
       PRINT "    1      A TEMPERARURE STRUCTURE PROFILE BASED ON DATA"
       PRINT "           AS PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398 "
       PRINT "           WHICH GIVES A HEIGHT TO THE -1.16 PROFILE"
   CASE 2
       PRINT "    2      A TEMPERARURE STRUCTURE PROFILE BASED ON DATA"
       PRINT "           AS PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398 "
       PRINT "           WHICH GIVES A HEIGHT TO THE -1.16 PROFILE"
       PRINT "           BUT WITH A FACTOR OF TWO TO APPROXIMATE"
       PRINT "           LOOKING UP A THERMAL PLOOM"
   CASE 3
       PRINT "    3      A TEMPERATURE STRUCTURE PROFILE BASED ON DATA"
       PRINT "           AS PRESENTED IN WALTERS/KUNDEL 1981 PAGE 398"
       PRINT "           FOR NIGHT CONDITIONS.  THE DEPENDENCE WITH"
       PRINT "           HEIGHT IS EXP(-.001*HEIGHT ABOVE 65 METERS"
```

```
      PRINT "              AND HEIGHT TO THE -1.46 BELOW 65 METERS"
   CASE 4
      PRINT "     4        A TEMPERATURE STRUCTURE PROFILE BASED ON A"
      PRINT "               HEIGHT TO THE -4/3 "
END SELECT
!
!
PRINT " "
!
!
PRINT "HIT CONTINUE TO CONTINUE"
PAUSE
OUTPUT KBD;"K";
!
GRAPHICS ON
VIEWPORT 15,120,10,70
!PLOT RANGE VERSUS NOISE
!
Xmin=-18
Xmax=-13
Ymax=4
Ymin=2
Dx=1
Dy=1
Yrange=2
Xrange=5
WINDOW Xmin,Xmax,Ymin,Ymax
AXES Dx,Dy,Xmin,Ymin,1,1
CLIP OFF
!
!LABEL PLOT
CSIZE 4,.6
LDIR 0
LORG 4
MOVE Xmin+.5*Xrange,Ymin+1*Yrange
LABEL "RANGE vs NOISE"
!LABEL HORIZONTAL AXES
LDIR 0
LORG 5
FOR J=Xmin TO Xmax STEP Dx
   CSIZE 4,.6
   MOVE J-.013*Xrange,Ymin-.067*Yrange
   LABEL "10"
   MOVE J+.013*Xrange,Ymin-.033*Yrange
   CSIZE 2
   LABEL J
NEXT J
MOVE Xmin+.5*Xrange,Ymin-.12*Yrange
LORG 5
CSIZE 4,.6
```

```
LABEL "NOISE  (WATTS)"
!LABEL VERTICAL AXES
LORG 8
FOR J=Ymin TO Ymax STEP Dy
   CSIZE 4,.6
   MOVE Xmin-.01*Xrange,J
   LABEL 10
   CSIZE 2
   MOVE Xmin-.0025*Xrange,J+.03*Yrange
   LABEL J
NEXT J
LDIR PI/2
LORG 6
MOVE Xmin-.1*Xrange,Ymin+.5*Yrange
CSIZE 4,.6
LABEL "RANGE  (METERS)"
CLIP ON
Ind=1
Noise=1.E-18
FOR Ind=1 TO 5
   PLOT LGT(Noise),LGT(Ran(Ind))
   Noise=Noise*10
NEXT Ind
!
PRINT "HIT CONTINUE TO CONTINUE"
PAUSE
GCLEAR
OUTPUT KBD;"K";
!
!
LINPUT "WOULD YOU LIKE TO MAKE ANOTHER RUN (ENTER Y OR N)?",X$
Again=FNYes(X$)
Mess_up=1
WHILE Mess_up=1
 SELECT Again
   CASE 1
        LINPUT "WOULD YOU LIKE TO CHANGE A VARIABLE (ENTER Y OR N)?",X$
         New_va=FNYes(X$)
         Ano_change=1
         WHILE Ano_change=1
           SELECT New_va
              CASE 1
               PRINT "      VARIABLE           CURRENT VALUE"
               PRINT USING "K";"1  TEMPERATURE           ",Temp,"CELSIUS"
               PRINT USING "K";"2  ATOMOSPHERIC PRESSURE ",Atom_pres,"mb"
               PRINT USING "K";"3  WATER VAPOR PRESSURE ",Wat_pres,"mb"
               PRINT " "
               PRINT USING "K";"4  ANTENNA DIAMETER      ",Ant_diam," m."
               PRINT USING "K";"5  PULSE LENGTH          ",Pulse," ms"
               PRINT USING "K";"6  POWER TRANSMITTED ",Pow_trans," WATTS"
```

```
                PRINT USING "K";"7  ATMOSPHERIC PROFILE  ",Profile
                PRINT " "
                PRINT "ENTER THE NUMBER OF THE VARIABLE YOU WISH TO"
                PRINT "CHANGE"
                INPUT Var
                SELECT Var
                         CASE 1
                            INPUT "TEMPERATURE=",Temp
                         CASE 2
                            INPUT "ATMOSPHERIC PRESSURE IN mb=",Atom_pres
                         CASE 3
                            INPUT "WATER VAPOR PRESSURE IN mb=",Wat_pres
                         CASE 4
                            INPUT "ANTENNA DIAMETER IN m.=",Ant_diam
                         CASE 5
                            INPUT "PULSE LENGTH IN ms=",Pulse
                         CASE 6
                            INPUT "POWER TRANSMITTED IN WATTS=",Pow_trans
                         CASE 7
                           PRINT " 1  ==> Ct^2 PROFILE OF Z^(-1.16)"
                           PRINT "         FROM WALTERS/KUNDEL 1981"
                           PRINT " 2  ==> SAME AS ONE BUT WITH FACTOR"
                           PRINT "         OF TWO TO APPROXIMATE LOOKING"
                           PRINT "         UP A THERMAL PLOOM"
                           PRINT " 3  ==> Ct^2 PROFILE OF EXP(-.001*Z)"
                           PRINT "         FROM WALTERS/KUNDEL 1981."
                           PRINT " 4  ==> CT^2 PROFILE OF Z^(-4/3)"
                           INPUT "ENTER NUMBER OF DESIRED PROFILE",Profile
                           IF Profile=4 THEN
                            INPUT "HEIGHT OF INVERSION IN METERS=",Inver
                           END IF
                         CASE ELSE
                           PRINT Var,"IS NOT ONE OF THE OPTIONS"
                    END SELECT
                    LINPUT "MADE ANOTHER CHANGE(ENTER Y OR N)?",X$
                    New_va=FNYes(X$)
                    Mess_up=2
               CASE 2
                    Mess_up=2
                    Ano_change=2
               CASE ELSE
                    PRINT "YOUR CHOICES WHERE Y OR N !!!!!"
                    Ano_change=1
                    LINPUT "CHANGE A VARIABLE (ENTER Y OR N)?",X$
                    New_va=FNYes(X$)
           END SELECT
        END WHILE
    CASE 2
        Mess_up=2
    CASE ELSE
```

```
        PRINT "YOUR CHOICES WHERE Y OR N  !!!!!!"
        Mess_up=1
        LINPUT "MAKE ANOTHER RUN (ENTER Y OR N)?",X$
        Again=FNYes(X$)
   END SELECT
  END WHILE
END WHILE
PRINT "THAT'S ALL, FOLKS"
end
!
!
!CALCULTE THE ATTENUATION
sub Attenuation(Atom_pres,Atten,Freq,Temp,Wat_pres)
!THIS SUBPROGRAM CALCULATES THE ATTENUATION OF SOUND
!IN AIR BASED UPON EQUATIONS IN NEFF 1975
!
!   INPUT    ATMOSPHERIC PRESSURE IN MILLIBARS
!            FREQUENCY OF SOUND WAVE IN HERTZ
!            TEMPERATURE IN DEGREES CELCIUS
!            WATER-VAPOR PRESSURE IN MILLIBARS
!
!   OUTPUT   ATTENUATION IN 1/METERS
!
!VARIABLES
!  Atom_pres  INPUT OF ATMOSPHERIC PRESSURE IN mb.
!  Atten      ATTENUATION OF ACOUSTIC WAVE.  CALCULATED IN
!              SUBPROGRAM ATTENUATION.
!  Att_max    VARIABLE IN SUBPROGRAM ATTENUATION.  IT IS THE
!              ATTENUATION AT THE FREQUENCY OF THE MAXIMUM
!              ATTENUATION FOR THE INPUT CONDITIONS.
!  F          VARIABLE USED IN SUBPROGRAM ATTENUATION.  IS THE
!              RATIO OF FREQUENCY TO FREQUENCY AT MAXIMUM ATTENUATION.
!  Fmax       FREQUENCY OF MAXIMUM ATTENUATION. USED IN SUBPROGRAM
!              ATTENUATION.
!  Freq       INPUT FREQUENCY OF ECHOSOUNDER.
!  H          VARIABLE USED IN INTEGRATION FOR EXCESS ATTENUATION.
!  Pstar      VARIABLE USED IN SUBPROGRAM ATTENUATION FOR INTERMEDIATE
!              CALCULATION.
!  Temp       INPUT TEMPERATURE IN DEGREES CELSIUS.
!  Tstar      INTERMEDIATE VALUE USED IN CALCULATION OF ATTENUATION
!              IN SUBPROGRAM ATTENUATION.
!  Wat_pres   ATMOSPHERIC WATER PRESSURE IN MILLIBARS.  INPUT BY
!              OPERATOR.
 H=100*Wat_pres/Atom_pres
 Tstar=(1.8*Temp+492)/519
 Pstar=Atom_pres/1014
 Fmax=(10+6600*H+44400*H*H)*Pstar/Tstar^.8
 Att_max=.0078*Fmax*Tstar^(-2.5)*EXP(7.77*(1-1/Tstar))
 F=Freq/Fmax
 Atten=(Att_max/304.8)*((.18*F)^2+(2*F*F/(1+F*F))^2)^.5
```

```
Atten=(Atten+1.74E-10*Freq*Freq)/4.35
SUBEND
!
def FNYes(X$)
!THIS FUNCTION INTERPRETS THE OPERATORS RESPONSES TO YES NO QUESTIONS
!
!     INPUT      X$
!
!     OUTPUT     FNYes
!VARIABLES
!   Temp$       VARIABLE STRING USED IN FUNCTION YES.
!   X$          STRING PASSED TO FUNCTION YES TO DETERMINE OPERATOR
!                RESPONSE TO YES OR NO QUESTION.
     DIM Temp$[1]
     Temp$[1,1]=TRIM$(X$)
     SELECT Temp$
     CASE "Y","y"
          RETURN 1
     CASE "N","n"
          RETURN 2
     CASE " "
          RETURN 1
     CASE ELSE
          RETURN -2
     END SELECT
FNEND
```

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END

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